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Metal Progress

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National Emergency Steels; NE 1300 Series

THIS SERIES (NE 1300) is of carbon-manganese steels in the medium carbon range, therefore of the semi-thorough hardening type and the thorough hardening type. The alloying element is inexpensive manganese, limiting range being 1.60 to 1.90%, and no incidental elements are anticipated in the chemical specification other than the usual amounts of silicon. The general position of the 1300 series in the carbon-manganese family of heat treated steels is shown in Fig. 1.

These steels are by no means new, having been long used by the U.S. Navy in the form of heavy heat treated forgings and having been contained in the S.A.E. list as the T 1300 series in substantially the same form (except for wider carbon limits) since 1935. Prior to their incorporation in the S.A.E. and A.I.S.I. list of alloy steels, they were contained in the General Motors Corp. standards, and many hundreds of heats of the G.M.C. analyses have been bought by that corporation in the last 15 years.

Uses — These manganese steels in the carbon range of 0.30 to 0.40% have therefore been very popular in the automotive industry for such parts as axle shafts, main bearing bolts, engine bolts, connecting rod bolts, studs, timing chain links, brake drums, flange yokes, sleeves, stud and ball yokes, flanges and so on. In industry in general, outlets for this grade of steel include pressure cylinders, logging and road machinery, gears, shafting, axles, pistons, miscellaneous bolts and studs, and many other machine parts.

The steels with a carbon content of 0.45 to 0.60% are widely used in making oil-hardened gears, axles, shafts, grinding balls and for other uses where abrasion resistance, high strength and fair ductility are required.

Millions of high explosive shell have been made in recent years of analysis conforming to S.A.E. T 1340; the required high physicals could be had with normalized metal, but an impending shortage of manganese caused a reduction in the manganese content and the adoption of heat treatment (quench and draw) to achieve the desired strength and ductility.

Manganese has long been known as a strengthener in steels. A structural steel which would classify as NE 1335 was used in as-rolled condition in the main members of the huge arch bridge built in 1929 over Kill Van Kull, south of New York City. (Strong structural steels of this type were continued by U.S. Steel Corp. under the trade name of "Man-Ten".) A 50% increase in strength

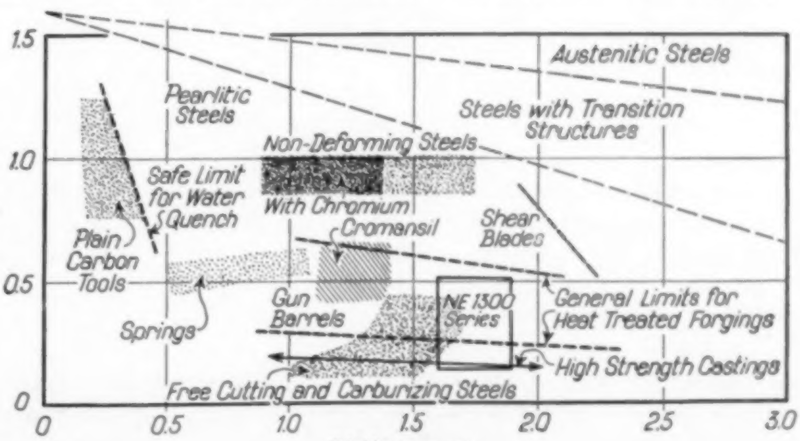


Fig. 1—Approximate Chemical Limits for Carbon-Manganese Steels Used in Heat Treated Condition

Table I — Acceptance Tests on 27 Heats of S.A.E. 1330-A Steels (Buick)
(1$\frac{7}{16}$ to 1$\frac{3}{4}$-In. Rounds, Forged to 1$\frac{1}{16}$-In. Round, Water Quenched From 1550° F., Drawn 2 Hr. at 900° F.)

Property	Arithmetic Average	Standard Deviation *(a)*	Extreme Values	
			Maximum	Minimum
Carbon content	0.300%	0.017	0.33	0.27
Manganese	1.725%	0.119	1.93	1.50
Grain size *(b)*	7	..	8	6
J-45 hardenability *(c)*	4.3	0.8	6.5	2.6
Ultimate strength	142,500 psi.	8,300	160,200	130,800
Yield point	130,400 psi.	12,100	151,800	111,900
Elongation in 2 in.	18.5%	1.1	20.5	16.25
Reduction of area	60.3%	2.3	64.4	55.8
P value *(d)*	100.82	1.92	103.57	96.49

(a) Three quarters of the observed values may be expected to fall within this range, plus or minus.
(b) By McQuaid-Ehn test.
(c) Distance in $\frac{1}{16}$ in. from end of Jominy test (end-quenched from 1550° F.) to reach Rockwell hardness of C-45.
(d) is $\frac{T+6R}{5}$ where T is the ultimate strength in 1000 psi. and R is the reduction of area in %.

in bridge columns made of this steel, as compared with members of the same design built of ordinary carbon structural steel, was proved by large-model tests made at the Bureau of Standards. Average results of mill tests from 168 heats of steel for this arch bridge were:

Analysis: 0.33% carbon, 1.63% manganese, 0.18% silicon

	Average	Specified Minimum
Ultimate strength	101,600 psi.	90,000
Yield point (drop of beam)	58,600 psi.	55,000
Elongation in 8 in.	19.5%	16
Reduction of area	42.6%	30

Manufacture — From the steel makers' viewpoint, the manganese alloy steels require a little more care than the other alloys, the manganese having a tendency to segregate in the ingot. However, the handling of scrap constitutes less of a problem, as the recovered manganese is an essential addition to *all* steels. Segregation is exhibited as a pronounced banding in the microstructure and, if banding is extreme, it is undesirable for the following reason: Unless the annealing of a badly banded steel is prolonged or repeated, the manganese will not have time to distribute itself more uniformly throughout the metal, and the high manganese regions will have sufficient hardenability to develop hard spots after cooling in air, with consequent damage to cutting tools, finish, and general machining properties.

Forgeability may be appraised by the following statement made in 1929 by the late Paul E. McKinney, describing practice at the U.S. Naval Gun Factory:

"We have had quite some experience in the manufacture of forgings from these high manganese steels as a result of which it is concluded that this grade of steel is generally freer from the normal defects found in forging stock and is capable of being forged into difficult shapes with greater ease and is generally superior both from the standpoint of forgeability and susceptibility to heat treatment than any of the carbon or alloy steels capable of being worked to equal physical properties. These characteristics, of course, apply only to steel that has been produced under proper melt practice, as this grade of steel requires at least the same careful attention in melt practice as is necessary in the production of the recognized alloy steels."

Buick Practice on 1330 and 1340

The following data represent practice at Buick Motor Division, General Motors Corp.:

The most important application for the 1330 type on the Buick car was for axle shafts. The shafts were taper-rolled on the body, and upset on the end forming a large flange. They were then water quenched (leaving the flange out of the water) and drawn to Brinell hardness of 341 to 388. All machining was performed after heat treating.

Table I shows acceptance tests on a series of

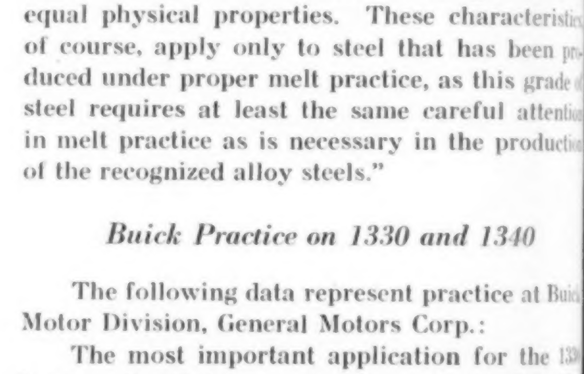


Fig. 2 — Influence of Carbon and Manganese on Ultimate Tensile Strength of NE 1300 Steels, in the Normalized Condition and After Quenching and Drawing 2 Hr. at 900° F.

27 heats during a period selected at random from recent records. Manganese increases the depth of hardening in steels and the hardenability of the NE1300 series is quite sufficient to harden the forged test bar to the center, so the effect of mass is avoided and the results in the table are indicative of the range of properties which may reasonably be expected throughout a moderately sized piece, quenched and drawn as specified.

Table II — Acceptance Tests on 26 Heats of S.A.E. 1340-A Steels (Buick)
(1-In. to 3¼-In. Squares; Average 1¾ In.; Forged to 1 1/16-In. Round, Oil Quenched From 1550° F., Drawn 2 Hr. at 900° F.)

Property	Arithmetic Average	Standard Deviation *(a)*	Extreme Values	
			Maximum	Minimum
Carbon content	0.404%	0.029	0.46	0.37
Manganese	1.839%	0.091	2.00	1.65
Grain size *(b)*	7	..	8	5
J-50 hardenability *(c)*	8.9	3.0	16.2	4.6
Ultimate strength	166,950 psi.	10,600	178,600	142,000
Yield point	154,400 psi.	14,300	168,200	119,600
Elongation in 2 in.	14.9%	0.7	16.0	12.75
Reduction of area	51.5%	2.8	56.9	45.1
P value *(d)*	95.2	2.8	99.0	90.8

Notes *(a)* to *(d)*, see Table I.

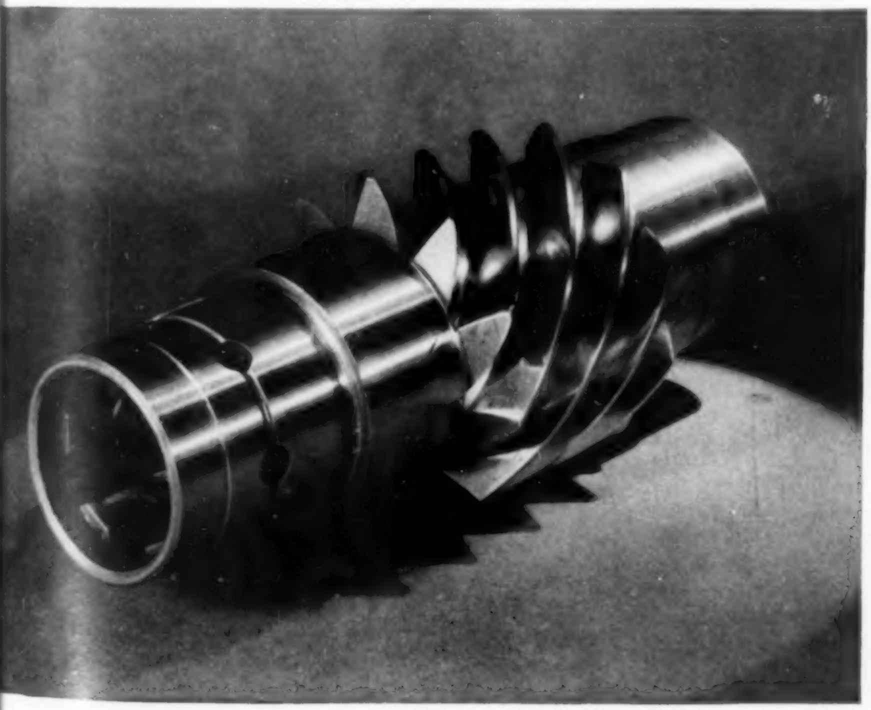
It will be noted that the manganese varies over a much wider range than the carbon, but manganese in the specified range has comparatively little effect on the properties as heat treated, as shown by the curves in Fig. 2. (Likewise, the "P" value, an appraisal of strength and ductility, is quite constant, the standard deviation of the recorded results being less than 2%.)

Izod or Charpy impact values of fine-grained 1300 steels are somewhat lower than nickel and nickel-chromium steels when hardened and then tempered to 200,000 psi. tensile, but are fully equal at the higher draws and tensiles shown in Tables I and II.

G.M.C. 1340 steels were substituted for S.A.E. 3100 steels (nickel-chromium) many years ago, and were found to act much like the old steels in all the manufacturing steps of forging, annealing, heat treating, and machining.

The G.M.C. 1340 transmission gears are annealed in a four-zone continuous furnace, 37 ft. long, with a capacity of 1250 lb. per hr. The zones are controlled at the following temperatures, starting at the charging end: 1575, 1575, 1180, 1180° F. The Brinell range set up for this job was 187 to 207, aiming at 197 to 207. The annealing cycle resulted in a pearlitic structure with about 10% of spheroidal cementite, a microstructure found to give the best all-around machining properties for this particular job.

Reference to the "S curves" of other steels (page 617 of October 1942 issue) will indicate that this annealing is of the "short cycle" type and heated the forgings 150° above the upper critical temperature ($Ac_3 = 1430°$ F.) and gave them about 2 hr. for carbides to go into solution in the austenite. Passing on into the cooler zone, the work was cooled fairly quickly to Ar_1, the lower critical on ordinary cooling, where the transformation from austenite to pearlite and ferrite (soft constituents) is most rapid. This transformation is completed while the temperature is held at or near Ar_1 (1180° F.) during the 2-hr. stay in the exit half of the furnace, and on emergence the gear blanks



are fully softened and can be cooled in any convenient manner.★

Table II is a summary of acceptance tests on 26 heats of these steels. Sizes ranged from 1-in. squares through $1\frac{7}{16}$ x $2\frac{3}{8}$-in. bars up to $3\frac{1}{4}$-in. squares. *Size* introduces no systematic variation in properties, when bars are forged to 1 in. and heat treated before testing.

Figure 2 again shows that manganese is not as important as carbon in determining properties, and so the analysis can tolerate greater variation in manganese content. As a matter of fact, the group of deliveries summarized in Table II would conform better to a specification of 1.70 to 2.00% manganese than the NE limits of 1.60 to 1.90. Generally no trouble would be encountered unless carbon and manganese were both at top limits.

limit on the J-50 or the J-45 measurement would need to be set. (For an interpretation of this test see *Metal Progress* for November 1940, p. 685.)

NE1345 for Tank Track Parts

Buick is at present using large quantities of NE1345 for end connectors, which constitute a part of the tank track. These parts are forged and then annealed using the following temperature cycle: 1450, 1450, 1180, 1180° F., which results in a Brinell hardness of 179 to 207. Resulting structure is lamellar pearlite with about 10% spheroidal. This structure and hardness seem to be entirely satisfactory to sub-contractors who machine these parts. (NE9445 is also used for this same job with the same annealing cycle and

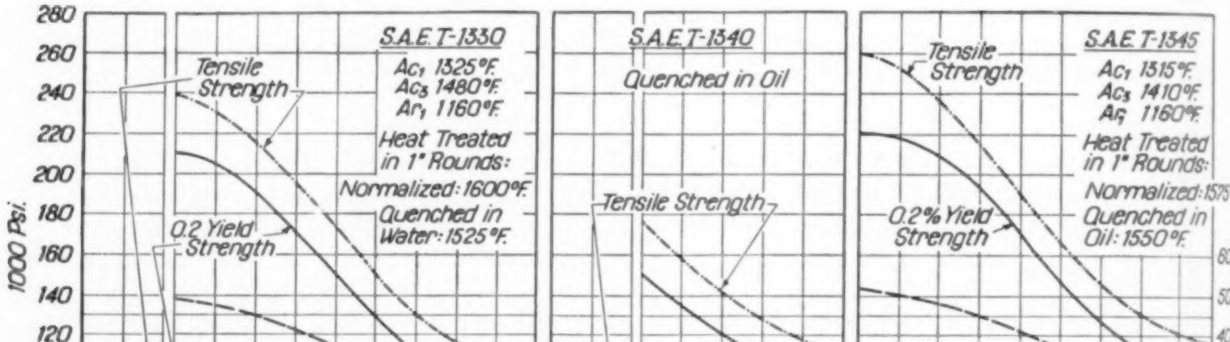


Fig. 3, 4 and 5—Tensile Properties and Hardness of Fine-Grained T1330, T1340 and T1445 (Courtesy Republic Steel Corp. and Bethlehem Steel Co.) After Various Heat Treatments on 1-In. Rounds. Values represent averages; safe minimums for ductility for a given strength will be represented by figures for drawing temperatures 300° F. lower

"P values" of these 1340 steels are not as high or as uniform as they are for 1330, but still the steels have excellent toughness even when reasonably hard. The largest variations in both the 1330 and the 1340 steels are in hardenability, as measured by the Jominy end-quench test. This is a matter which would be of greater importance in large pieces which would need to be hardened to the center, and in those cases a definite lower

the same hardness range as for the 1345. The structure obtained with the 9445 is entirely spheroidal with the configuration characteristic of molybdenum steels.)

Abrasion Resistance — One useful property of the "medium manganese" alloy steels of the NE1300 series that is difficult to express quantitatively is their superior abrasion resistance—doubtless one reason for their satisfactory use as gears. However, even in the as-rolled condition

★While complete "S curves" are not available, the effect of manganese on retarding the transformation from austenite to pearlite (and thus increasing the air hardening and depth hardening effect) may be judged from the fact that the time to start transformation at 1000° F. — close to the nose of the S curve — is 1 sec. for 1% manganese, 10 sec. for 2% manganese, and 400 sec. for 4% manganese, whereas it is only 2 sec. for 4% nickel in steel.

abrasion resisting steel bars and plates for launder liners, coke handling equipment, dredges and similar services have been marketed since 1930 by Carnegie-Illinois Steel Corp. as "AR" steel (NE1345 or 1350). At Brinell hardness of 200 to 250, varying inversely as the gage, this steel is readily fabricated by boiler shop methods, yet still gives two to three times the life of carbon steel.

Physical **Properties** charts of S.A.E. T1330, 1340 and 1345 are given in Fig. 3, 4 and 5. Average values given in Tables I and II for a draw of 900° F. may be compared with these curves, and should emphasize that any property will vary over a considerable range when results from numerous heats are compared. Graphs like Fig. 3 to 5 are therefore of most use in showing the *trend* the values will take when the drawing temperature is changed.

Annealing Practice

Annealing of the NE1300 series steels need cause no difficulty unless the manganese is badly segregated in the microstructure. In that case, the steel may be rescued by a long anneal at relatively high temperature (say, 6 hr. at 1700 to 1800° F.), followed by a low temperature normalizing at 1500° to refine the grain. (Double normalizing, once at 1500 and again at 1400° F., has also been recommended to suppress banding, refine the grain, decrease hardenability, and increase impact resistance.) If "cycle annealing" is impossible, a rapid cooling through the Ar_3 to Ar_1 range is desirable to avoid growth of ferrite envelopes and re-concentration of alloy, and from there on down a very slow cool.

NE1300 steels analyzing on the high side of manganese, especially the higher carbon steels, are much more susceptible to hard spots when supposedly in the machinable condition, since these steels, even when not segregated, have so much carbon and alloy as to be "air hardening" in almost any size. Consequently "cycle annealing" is most desirable, under schedules already given, holding the steel at around 1175° F. long enough for the complete transformation of the austenite. Otherwise, a slow cool in a furnace (or covered with lime) from 1200° F. at no faster rate than 5° per min. is necessary to avoid transformation of some of the austenite into hard martensite, even in a homogeneous microstructure.

Tendencies of the 1300 steels toward temper brittleness — that is, to lose toughness if slow cooled from the draw — are now seldom if ever encountered, since alloy steels now-a-days contain enough molybdenum to prevent it, this being picked up from the alloy scrap used.

Quench on Rising or Falling Heat?

By Metallurgicus

To MY MIND the injunction to "quench on a rising temperature" is an old saw that is outmoded by modern facilities; it, like engineering gray cast iron of 10,000 psi., the lost art of hardening copper, failure by crystallization of metal, and the use of White Rock for quenching, seems to me to be so remote from current practice based on knowledge that it belongs in the folk-lore of metallurgy.

Brearley's "Heat Treatment of Tool Steel" (published as long ago as 1916) says on page 89: "The usual works-practice is to quench out the steel from the highest heat attained; but there need be no hurry about it, as the temperature still has a long way to fall before it passes the lowest point at which the steel will harden." He goes on to point out the advantages of permitting the steel to cool toward Ar_3 before quenching.

It is of interest to note that Palmer's "Tool Steel Simplified" (1937) does not, so far as I can see, refer to the "rule". Harry Knowlton's "Heat Treatment, Uses, and Properties of Steel" tells us on page 413 that it is not necessary always to "quench on a rising heat", that, in fact, it is sometimes better to cool nearer Ar_3 before quenching.

Sherry's "Steel Treating Practice" tells us that the rule "do not harden on a falling heat" arose from the warpage and cracking due to incomplete hardening when the piece is quenched from within the Ar_3-Ar_1 range.

The reasons why such a "rule" ever was promulgated may be as follows:

1. Furnace temperatures before 1920 — and forge-fire heats — were generally inadequately controlled, and oscillations of 100 to 200° were to be expected. Of course, today *nobody* ever hardens a piece of steel except with pyrometric control — or am I wrong? Anyhow, when heating of that sort was necessary, obviously to avoid the inherent dangers of overheating (see also below) a rising heat — that is, catching the temperature as it rose — gave best likelihood of minimum overheating.

2. Since the "rule" is an old-timer, it may be assumed that carbon steels *(Cont. on page 752)*

An Eminent Living Metallurgist

John Johnston

Our Biographical Dictionary

John Johnston

Chemist
Metallurgist
Organizer of Research

IT HAS BEEN nearly 16 years since JOHN JOHNSTON became the first director of research of the United States Steel Corp. Nowadays, when a metallurgical company installs a research laboratory to probe into "pure science" no one is surprised or alarmed. But in the roaring 1920's, when every dollar in the business budget was supposed to triple itself or get out, fundamental science was understood to be the plaything of the universities, and the steel industry generally had little time for it. When, in 1927, Big Steel decided to spend money on a long view of science, the announcement understandably caused quite a stir. Even the New York *Times* congratulated the corporation in a cautious editorial entitled "Steel Turns to Research". However, it approved of the newly selected director of the laboratory without caution, saying: "Doctor JOHN JOHNSTON of Yale is a scientist ably qualified by technical education and experience to explore a field in which scientific and industrial honors are to be won."

Beyond doubt the Board of Directors of U. S. Steel were convinced that research was a good thing, but they were also a little nervous about the new baby, for the *Times* editorial continued: "Judge Gary's announcement of what his Board of Directors must have regarded as a daring innovation is phrased with . . . guarded optimism. The finance committee will keep an eye on the research laboratory."

That the late Judge Gary's optimism was indeed guarded is evidenced by some of his comments as reported in the press at the time of the announcement. He said, for example, "While the Corporation has no money to waste intentionally, we have money to expend if necessary." He said that the Board didn't expect miracles, "but," he added, "we will have patience. . ."

A less tough-fibered Scot than Dr. JOHNSTON might well have been discouraged at the start by this doubletalk and guarded optimism. However, late in 1928 the new laboratory had its beginnings in some unoccupied rooms at Federal Shipbuilding Co.'s offices, and today — more than 15 years later — this laboratory at Kearny, near Newark, N. J., is as important to U. S. Steel as the Mesaba Range. The director of research was a notable man in the field of chemistry long before he came to Kearny, and his stewardship there has added to his professional stature. He has elevated the standards of steel making in the Corporation and, indirectly, the technique of manufacture in general throughout the world. For a long time now the Board of Directors has stopped holding its breath, and the finance committee has found other things to keep its eye on.

JOHN JOHNSTON was born in Perth, the entrance to the Scottish highlands, and remains essentially a Scot in everything that matters. He is not the Sir Harry Lauder type of professional Scot, or the "hoot mon" character in the dialect stories, but rather a quiet, keen, long-faced man with equal parts of dourness and humor, both carefully restrained. An unusual number of philosophers and scientists have been nurtured by the ruggedness of Scotland and the uncompromisingness of Calvinism, and JOHNSTON is an exemplar of the cerebral Scot. He is, as they say on the whiskey labels, "distilled in Scotland".

Even for a scientist, JOHNSTON has had an impressively complicated scholastic career, punctuated at intervals by Hon. D.Sc.'s and Hon. M.A.'s, a two-year fellowship in Germany, and teaching chores at M.I.T. and Yale, but at heart he's a St. Andrews man, from which university he received his B.Sc. and his Doctorate. The whole list of his honors, with dates, is tabulated in "Who's Who" if anyone ever has to memorize it. The fellowship in Germany was at the University of Breslau where, beginning in 1905, he worked for two years under Dr. Abegg, who was, on the side, an amateur balloonist — a fatal hobby.

When Dr. JOHNSTON came to America in 1907 he expected to remain here about a year. He is still here. His first year was spent as a research associate in physical chemistry at Massachusetts Institute of Technology where he worked under Professor Noyes on the conductivity of aqueous salt solutions. In 1908 he joined the staff of the Geophysical Laboratory of the Carnegie Institution in Washington to investigate the behavior

of various substances at high temperature and pressure, to serve as a guide in the interpretation of geological phenomena. In this same year he married DOROTHY HOPKINS; they have three children, a daughter and two sons, all now grown up and married.

After eight years in Washington he went to St. Louis to head the research department of the American Zinc, Lead and Smelting Co., and so broke into the metallurgical profession, but this job was soon cut short by our entrance into the World War, at which time the Bureau of Mines asked him to help investigate war gases then under intensive study. Early in 1918 he became secretary of the newly formed National Research Council, which was (and still is) mobilizing the scientific talent of the country for the war effort. At the war's end he was chairman of the Council's Division of Chemistry. For the next seven years Dr. JOHNSTON taught with distinction at Yale where he was the first Sterling Professor of Chemistry, and later Chairman of the Chemistry Department. It was in 1927, as we said in the first place, that U. S. Steel Corp. called him to direct its new general research laboratory.

Before that time the several subsidiaries of the Corporation had carried on research, but each branch was interested primarily in its immediate operating problems, and very little was intentionally devoted to general studies applicable to the entire industry, or on fundamental problems that might return dividends at some future time. What Dr. JOHNSTON was able to do in his new laboratory was to survey the possibilities of improving the quality, and fitness for its purpose, of his company's chief product — steel — and to study the auxiliary materials and machinery necessary for its production. Much of the laboratory's work has been to determine the precise temperatures at which chemical and physical changes take place in steel and its alloys, and the time required for these changes. An outstanding instance is the development of the "S-curves", and the interpretation with their help of many obscure facts concerning wire manufacture and the heat treatment of toolsteels and engineering steels generally. The exact knowledge of these things has led to better control of the properties of the finished product, and has helped to improve operation and economy in many industries, especially those that require special steels. Not only has the proportional amount of the special steels been doubled and redoubled, but there has also been an appreciable reduction in the scrap produced and the weight of fabricated steel actually used in many industries. All of this is of course familiar to metallurgists and to those who have followed the many technical contributions from the Corporation's laboratory to ⊕ *Transactions* and other journals during the past 15 years.

The success of the laboratory's work may ultimately be attributed to the genius of a man now long dead — Willard Gibbs, the great 19th-century Yale mathematician. Gibbs's phase rule and his work on equilibrium in heterogeneous systems are the basis, says JOHNSTON, of much of the fruitful metallurgical research being carried on today, and will make possible infinite advances in technology as his ideas are more generally understood and applied. JOHNSTON is a devoted disciple of Gibbs and ranks him high among the great scientists of all time.

Today much of Dr. JOHNSTON's work involves war problems submitted by various branches of the Government. He is an active member of the War Metallurgy Committee, and while the nature of this work is irrelevant here, it is significant that the foresight of U. S. Steel in maintaining a laboratory for the study of pure science is now paying dividends to the nation in war, just as it contributed to the technology of peacetime. The success of such a laboratory depends largely on the quality of its personnel, and Dr. JOHNSTON has been at pains to surround himself with men of high calibre. Mere professional competence is not enough, he thinks, in men who do this kind of work; imagination and resourcefulness are also needed.

Dr. JOHNSTON is a constitutionally modest man, given to temperate judgments. When asked recently whether he had any pet hates, he considered his answer for a full minute before giving it. "Sham," he said. He can talk easily and at length about his work, or his associates, or about steel, and of course about Willard Gibbs, but when the conversation turns to himself he becomes monosyllabic and slightly uncomfortable. He admits, however, that for more than 30 years he and his family have spent their vacations on Mt. Desert Island off the coast of Maine. Mt. Desert (Bar Harbor) is the place where every good professor wants to go before he dies. Here, every summer, the learned doctors from the great universities, with their tweeds and their pipes and their children, gather to relax and play tennis and picnic, and — according to tradition — to exchange repartee in Latin. If a tidal wave were to wash over the island at the height of the season, learning in America would be crippled for 50 years to come. To the question, then, of what Dr. JOHNSTON does when he is not applying the phase rule, this 30-year habit may indicate the answer.

EDWARD C. MCDOWELL

By Alfred V. de Forest
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Massachusetts Institute of Technology
Cambridge, Mass.

New Pathways in Engineering

In the "reduction to metal" of any machine or structure, the engineer is faced with at least four general problems. These problems are best explained by an example, as of a bridge, particularly of a new type such as was the Eads Bridge over the Mississippi at St. Louis in 1880. They arise in the following order:

1. What loads are to be carried at what deflections? (These include both the dead load of the structure itself, and the live loads of traffic, present and future, plus the loads of snow and wind and the effect of temperature variations on the dead load.)

2. The useful strength of the available materials to be used in construction.

3. The details of the design, including connections and fittings, taking into account all the stress distributions, whether around bolts and rivets, or among the main or secondary members involving redundancy.

4. The local strength of the metals used, as influenced by unforeseen defects and variations, such as forging and casting defects, cracks due to welds or heat treatment, or other causes of serious local weakness. In general this problem is one of the *reliability* of materials, rather than their average performance.

There is a further general subject common to all structures and machines — that of upkeep and operation. In the case of a bridge this is primarily corrosion protection, but in machinery, wear and lubrication would be included. This phase will not be treated in the following discussion, which is a briefed version of a talk before the Philadelphia Chapter, ⊕, in January 1943.

The four "problems" are divided somewhat arbitrarily, but the division assists in giving a clear picture of the application of several new techniques available for their solution (and some of these new techniques will be described in what follows). All these problems must be considered by the engineer in their relation with each other, as improvement in methods of solving any one of them may influence the remainder.

Improved methods of calculation in the growing field of applied mechanics have greatly assisted the solution of the first problem. In the case of wind loads on bridges, great improvements have taken place by including vibratory aerodynamic forces as well as considering only static loads. Neglect of vibration, set up by wind loads, wrecked a big suspension bridge in Washington, only recently.

New Strain Gages for Measuring Loads

However, many questions of loads and their distribution can best be approached from the experimental side, and I wish to mention a newcomer in this field, the resistance-wire-strain gage. This device, due to Simmons of California Institute of Technology, and in its working form to Ruge of Massachusetts Institute of Technology, consists in a small grid of one-mil wire supported by paper or plastic and cemented firmly on the spot where strains are to be measured. When stretched the wire changes its electrical resistance linearly with the stretch (strain) even beyond the elastic limit of the wire. Static or dynamic strains up to the highest rates of explosive loading may be measured or recorded with any required degree of sensitivity above a millionth of an inch per inch. The limit of usefulness is up into the plastic range of the metals.

Such strain gages are particularly good for measuring dynamic working loads that cannot be readily calculated, as well as in proving the validity of different assumptions as to natural periods and modes of vibration. The first reliable

measurements of airplane propeller stresses were derived from carbon-resistance gages,[1] the forerunners of the wire gage. Many measurements of loads in airplane structures during test maneuvers are recorded on multi-element oscillographs — or by the latest recording system in which the changes in gage resistance are used to modulate the frequency of a short radio wave, transmitting to the laboratory oscillograph the strains during test flight from distances up to 150 miles!

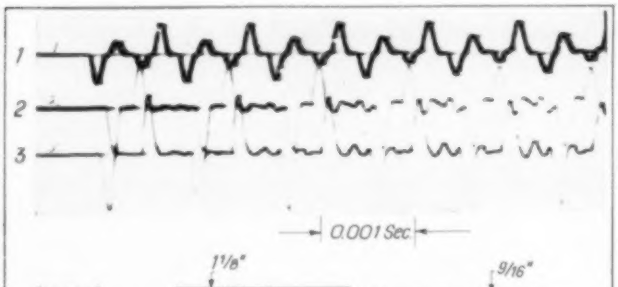


Fig. 1 — Cathode-Ray Oscillographs Showing Partial Reflection of Elastic Strain Waves at Change of Section in Steel Bar. Gages are located at 1, 2, and 3. Freely suspended bar was struck on end by a hammer

Fig. 1. This example was described in Reference 2 and can be nicely worked out analytically by means of DeJuhasz' graphic dynamic method,[3] but with more complicated conditions the analysis is more difficult.

Figure 2 illustrates the hoop tension strains occurring at the powder chamber, the center of the barrel and the muzzle of a semi-automatic 30-caliber rifle of the recoil type. Also shown is the elastic train of longitudinal strain waves, set up in the barrel by its impact on the breech; these correspond to the fundamental mode of vibration. Other measurements were made to determine the whip or bending vibration, which in all other types of guns deforms the barrel before the bullet has reached the muzzle. It is apparent that in this gun barrel the whip due to the propellent powder is but a fraction of that due to the vibration set up when the recoiling barrel hits the breech.

A compact strain indicator for essentially static loads is shown in Fig. 3. This device measures 12 x 9 x 6 in., weighs 25 lb., operates from self-contained batteries, and is graduated in micro-inches. This device is operated from a 1000-cycle current and is a null instrument. Neither temperature, vibration nor gravity field affects its accuracy.

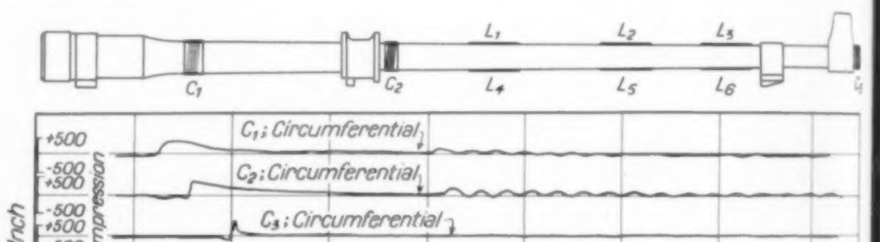


Fig. 2 — Strains Set Up in Barrel of Johnson Semi-Automatic 30-Caliber Rifle on Firing a Round and Subsequent Recoil Against Breech. Sketch shows location of elastic strain gages

Rapid loading, such as occurs in impact testing machines and steam hammers, develops stresses notoriously difficult to calculate, but which are easily measured with wire gages and commercial cathode-ray oscillographs. This class of problem deals with the propagation and reflection of elastic waves, which in steel travel at 17,000 ft. per sec., and in any but the simplest cases are difficult to handle analytically. The partial reflection of elastic strain waves at a change in diameter of a steel bar is illustrated in

Figure 4 is a scanning recorder, which automatically records the strains at 48 gage points in a period of 3 min., and is particularly suited for following strains in aircraft structures during shop testing. After each complete cycle of recordings the applied loads are changed and a new set of readings placed on the same chart. Eight

[1]Superscripts refer to the bibliography, at end of article, page 752.

readings of each gage, or 384 readings, may be made before changing to a new paper disk. This is also a 1000-cycle bridge on the null system.

Experience so far indicates that the wire gage seems well adapted to improve our knowledge of working loads and stress distribution, and thereby to assist greatly in obtaining rapid answers to the first problem — that of anticipated loads.

Strength of Materials

The second problem, that of the strength of materials, is fairly well understood by readers of *Metal Progress*, for this is in the field of metallurgy — a fertile and well-plowed land, as may be plainly seen at any meeting of the American Society for Metals. The history of great events such as the Eads Bridge shows that this was not always so, for 65 years ago the engineer had to invent his materials to suit his needs, devise full-scale testing machines to prove his conclusions, beg and bribe steel makers to obey his instructions, and brow-beat investors into supporting his enterprise.

Now, conditions have changed in some of these respects; especially is the basic strength of materials better known and more carefully controlled. Defective or sub-standard metals present less likelihood of disaster than any of the problems we have outlined. Metallurgy is becoming a science as well as an art, with abundant resources of skilled man-hours and great treasure at its disposal, and in its sweeping advance has often progressed beyond the ability of designing and construction engineers to keep in step. Faced with the shortage of metals due to war production we find that in very many cases too much, too specialized, too expensive, and too elegant a base material has been too freely used in our engineering, and the shortage is now giving us an opportunity to appraise and rectify these errors of a period of over-abundance.

Tools for the Stress Analyst

The third problem, that of refinement of design, is therefore becoming recognized, and a group of specialists is developing from the engineering ranks under the name of stress analysts. As is to be expected, the greatest urge comes from the aircraft field, for there excess weight is economically most expensive. In both the airplane and its power plant, dead weight is important, but because inertia loads are involved, any reduction of weight will remove a far greater proportion of the load than in a corresponding static structure. For instance, a lighter piston means less inertia load on the piston rod, which in turn may then be made lighter, resulting in a lighter crankshaft, less vibration and a lighter crankcase. In this way a pound removed from the piston may mean several pounds removed from the engine as a whole.

A most useful tool in the hands of the stress analyst has been provided by those other specialists, the photo-elasticians. The recent extension of photo-elastic measurements into the third dimension has made this method all the more valuable to engineers, and equipment for examining sheet models in two dimensions is now a part of all well-equipped laboratories.

Fig. 3 — Null Point Strain Indicator for Measuring Micro-Strains

Less recondite tools for stress analysis are provided by brittle coatings and by resistance wire gages — frequently in conjunction with each other. Under the trade name of Stresscoat, brittle lacquer has been widely used.[4] The method consists in spraying a part or an assembly of parts with a coating which cracks well below the elastic limit of the metal, plastic or wood under investigation. If loaded progressively, the spots of maximum strain are indicated by the local cracking of the lacquer, even though the region is a fillet, the root of a screw thread, or metal surrounding an oil hole. The sensitivity of the

lacquer in each test is determined by a calibrating bar, coated, dried, and loaded at the same time as the test. Full-size parts or models may be used, or models of different and more convenient materials. For instance, sand-cast aluminum crankshafts may be substituted for steel forgings, and the model may be whittled down in the regions of low stress to arbitrarily reach a better design. Very nice work of this kind can be done with plastic, cast in rubber molds.

The brittle coating cracks along the lines of maximum resolved tension. Stress direction is often an important part of the problem for, knowing this, simpler forms of calculation are often possible. While the lacquer only cracks in tension, compression strains may be indicated by applying the test load *before* the coating has dried, and then observing the cracks which result on the release of load. Due to the primary creep in the lacquer, it is frequently possible to observe the crack pattern produced by tension during loading, then hold the part under tension for a few hours, allowing the coating to reach equilibrium, and on relaxing the load, to observe the strain distribution which would result from compression.

Very often the distribution of strain resulting from impact is important. In this case the lacquer is particularly useful, for no other method of obtaining an over-all picture is available. Cracks in the lacquer are visible only because they are open by more than one-quarter the wave length of light, even after the load causing the cracks has been removed. When the loading is extremely rapid the cracks frequently cannot be seen, but they may be developed by suitable etching. Just as invisibly tight cracks in steel may be located by a corrodent attacking its edges, so a wash with the proper solvent opens the invisible cracks in the lacquer, and a dye may then be introduced. This colored line is especially suitable for photography, and is an aid in examining large areas — for the usual method of locating cracks requires oblique light to see the internally reflecting surfaces, and when cracks are sharply curved their direction is difficult to follow.

Needless to say, brittle lacquers have rigid limitations. It is only possible to get quantitative results where temperature, rate of loading, and sequence of loads may be controlled, and the strains are at least 0.0006 to 0.0007 in. per in., corresponding to 18,000 to 21,000 psi. in steel. The practical working limits of lacquer thickness are 0.003 and 0.005 in., and the minimum spacing of the cracks is of the order of four to five times this thickness, so that a "gage length" of 0.012 to 0.025 in. is about the minimum for normal use. A thinner coating may be obtained, but is difficult to control in any quantitative manner, although Fig. 5 shows the stress distribution across a spot weld with cracks 0.002 in. apart.

Resistance wire gages are particularly well

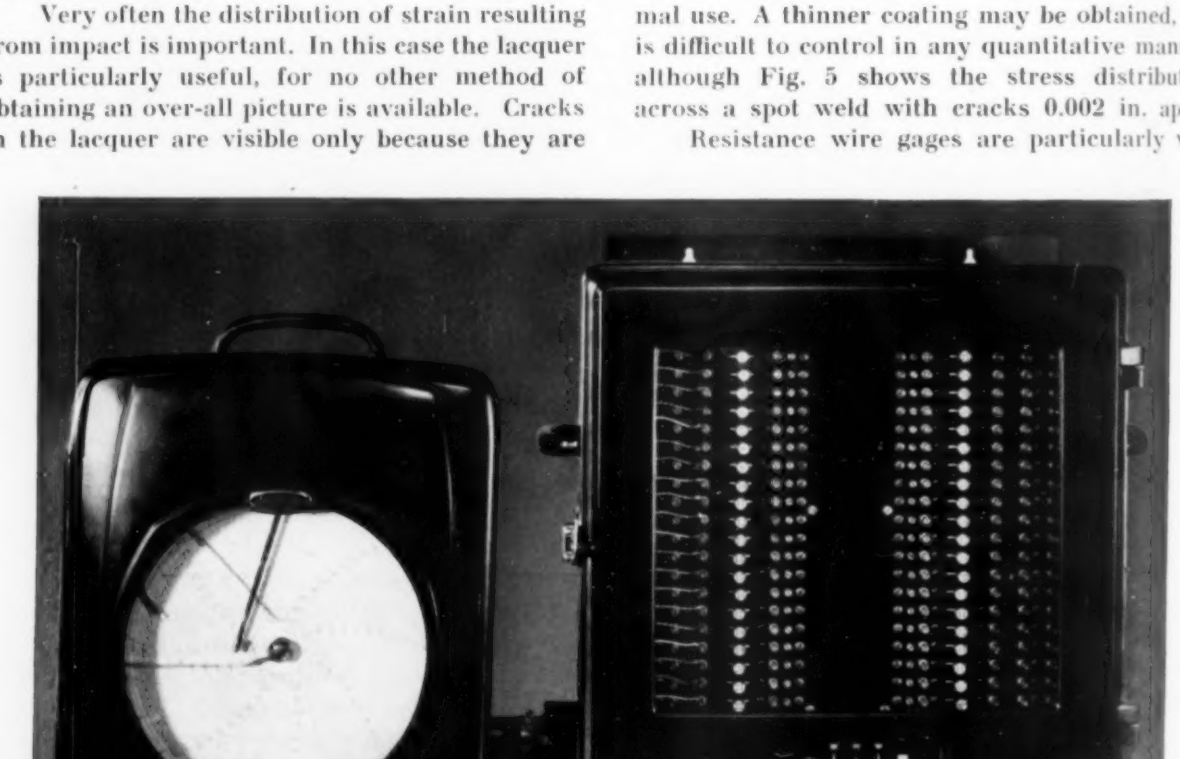


Fig. 4 — Recorder for 48 Elastic Strain Gages

suited for accurate measurements of strain distribution over gage lengths of more than ⅛ in. where the strain direction is known, and may be placed in directions radiating out from a spot being investigated where the complete elipse of stress is required. The combination of brittle lacquer for the qualitative determination and wire gages for quantitative measurements is frequently useful. Temperatures up to about 400° F. may be used, with baked-on gages of good long-time stability. Creep of plastics at various temperatures has been successfully measured.

Many other types of strain measurements are in common use, and an excellent discussion of all the well-known methods is described by Lipson in a recent paper before the Society for Automotive Engineers.[5] By whatever methods it be accomplished, the problem of stress analysis — the art and science of streamlining stress distribution — is of the most importance. It is almost always possible to strengthen and lighten and cheapen a part by analyzing its stresses in service. This point is important to metallurgists, for in the great majority of failures, the blame is visited on them "even unto the third and fourth generation", rather than on the design engineer.

Discovery of Local Defects

The fourth general problem is that of purely local defects. Good engineering calls for a factor variously called that of safety or ignorance! This factor depends largely on fear — fear of unknown load, fear of untested metallurgical strength, fear of unforeseen stress concentration, fear of hidden defects. Radiography was developed to answer this problem, as was the magnetic particle method and the fluorescent penetrating oil — all as additions or extensions of visual inspection.

A simple and primitive example will illustrate several phases of local weakness. Suppose a woodworker is making oars of ash. He would select timber with a straight grain and free from knots and would shape the blade at such an angle as to have the minimum of cross grain. Because he can see all these factors he can make all his oars equally dependable. If he could see only the outline surface of his wood, his oars must all be heavier if they are not to show great variation in useful strength — in other words, he would use a much higher factor of ignorance. If he had a quantity production machine, he might make all the oars to a design suitable for straight grain and no knots and, by inspection, reject those which came through production with defects in these variables.

In modern metal manufacturing, three choices are present and are combined differently to maintain an economic balance:

1. Design for flawless raw material and introduce no flaws in the process. This solution demands extremely rigorous control which is frequently more expensive than either of the following.

2. Design with a sufficient factor of safety to care for all reasonable defects. This method is the one commonly used but wastes metal.

3. Design as in choice No. 1, but supply an inspection system to catch the occasional defect in raw material or processing. This choice is rapidly becoming the most economical by virtue of the present status of non-destructive testing and inspection.

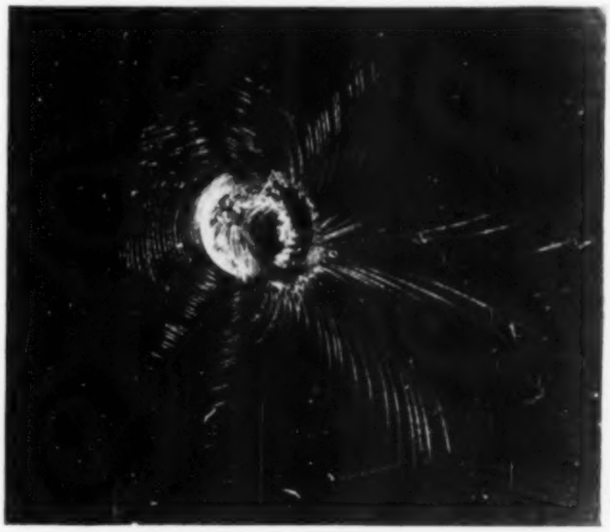


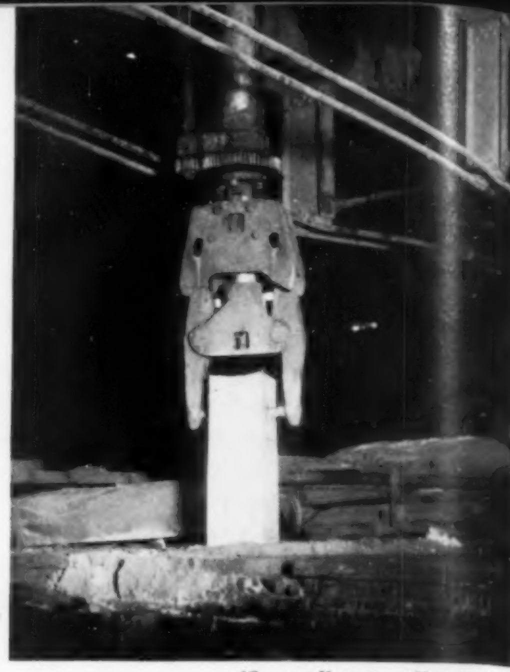
Fig. 5 — Stresscoat Pattern at a Spot Weld (Magnified 5 Times)

No manufacturer wishes to burden himself with 100% inspection, but nevertheless such a system has been in use for the past six years in the aircraft engine field where every heavily loaded steel part is inspected by the magnetic particle or Magnaflux method[6] and non-magnetic parts are X-ray inspected in enormous quantities.

A still newer inspection system applicable to metals, plastics and ceramics is now coming rapidly into use. This is the fluorescent penetrating oil method. Surface cracks only can be found, but in very many cases these surface cracks are dangerous. Full-scale, 100% application of this system is in use on one manufacturer's airplane engine cylinder heads, and many laboratory test units are proving successful. Apart from questions of strength, this inspection is successful in showing flaws in tungsten wire and rod used in the vacuum-tube industry, where air leakage through the metal *(Continued on page 750)*

War Products

Consultation



(Courtesy Youngstown Sheet & Tube Co.)

Heating of Heavy Forging Billets

The Problem

Posed by a Shipyard

WE ARE MAKING many heavy forgings from plain carbon steel (0.40% carbon) starting with billets about 25 in. square. It is our desire to cut heating time to a minimum, but still not jeopardize the quality of the resultant forgings by the possible presence of hidden cracks or internal bursts.

Recommendations

From a Midwestern Forge Plant

The problem is one of avoiding gross internal ruptures due to stresses caused by high temperature gradients from center to outside, rather than "flakes" or "hidden thermal ruptures" which are formed when the steel (which has absorbed hydrogen from some source) cools through a range around 300° F. — that is, before it is nearly cold. Our heating practice has been pointed toward the use of ample time in bringing steel up to a temperature of 1800 or 1900° F. and accelerating the rate of heating only after such a temperature has been gained uniformly. In a batch type of furnace we would charge blooms when the furnace is low in temperature and consume 6 or 8 hr. in heating and soaking.

From a Maker of Fine Steels

Internal cracks or "bursts" are, in our opinion, due most frequently to poor steel melting practice, rather than subsequent processing. Some forging defects may originate in the shape of the bottom die — whether a plain anvil or a Vee-shaped die.

To expedite heating we would maintain one pit, holding several billets, at about 1300° F., and then transfer the steel to a hot pit for final heating. (In a hearth furnace the billets should be turned bottom side up at least once.) We would expect to heat a 25-in., 10,000-lb. ingot from 70° F. to forging heat in 9 hr.

Square billets are more difficult to heat and forge than round, octagonal or fluted sections and should be avoided unless the forging's shape actually requires it.

From a Manufacturer of Die Blocks

While most of our work is on ingots that have never gone cold, sometimes cold billets must be handled. We then place them in front of the forge furnace door for a day. The furnace tem-

perature is dropped to about 1000 to 1200° F. and the ingot or billet — which has acquired 300 to 400° of temperature — is then placed in the furnace, which is held for 2 or 3 hr. without firing. The furnace is then lit and heated very slowly for several hours to permit the billet to absorb considerable heat before turning on the full blast of the burners. Our furnaces are rather large and in order to fill the furnace we would charge three or four 25-in. billets. Such a furnace would naturally consume more time in bringing the billets or ingots up to forging temperature, but for a single billet, we could have a 25-in. billet ready in 10 to 12 hr. after charging.

From a Maker of Heavy Industrial Machinery

Our practice would be to charge several of these 25-in. billets on a car-type preheating furnace whose temperature is not over 300° F. We would heat slowly and uniformly to approximately 1200° F., taking about 12 hr. Billets would then be transferred to a forging furnace whose temperature is between 1200 and 1300° F., and brought up to 2150 to 2250° F. in about 8 hr.; they would then be ready for forging.

In extremely cold weather we would first load the billets into a tank of cold water, temperature 45°, then turn exhaust steam into the tank until the water is heated nearly to boiling.

From a Gun Plant

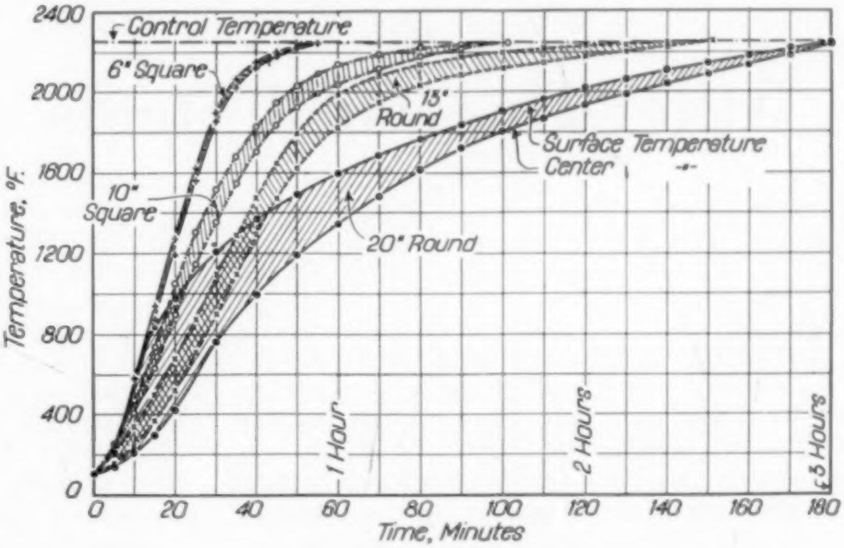
Assuming that the billets are at least 60° F., preheat to 200 to 300° F. by laying in front of a hot forge furnace for 24 hr. (roll billet over when 12 hr. has elapsed), charge in furnace at 700 to 900° F., hold at 700 to 900° F. for 2 to 4 hr., heat to 1500° F. at 75 to 100° per hr., *hold at 1500 to 1600° F. for 5 hr.*, then heat to forge temperature of 2225 to 2300° F. at 100° per hr., hold at forge temperature for 8 to 16 hr., depending on the amount and type of forging to be done.

From a Naval Ordnance Plant

We would allow the forge furnace to cool to 1200 to 1300° F., charge the billets and leave the doors open without any flame for about 2 hr., then close the doors and allow to soak for about 1 hr. more. We would then fire the furnace as rapidly as possible to forging temperature.

From a Furnace Manufacturer

Most forge furnaces have roofs that are too low — that is, the *volume* of the furnace is so small that heat cannot be generated in it at a rate the steel can safely absorb. In other words, time can be saved in the heating cycle by increasing the volume of the combustion chamber. The steel can absorb the heat, as proved by experiments reported to the American Gas Association in 1942 and summarized in the graphs. They show that heating rates (to a constant furnace temperature)



Time-Temperature Curves for Surface and Center of Round Billets, Charged in a Hot 7 x 11-Ft. Forge Furnace, Gas Fired From Both Sides Above the Charge. Billets rested on solid hearth

are unexpectedly high, and that temperature differentials, surface to center, are unexpectedly low. The rate at which steel can absorb heat can be computed from these curves and turns out to be in the neighborhood of 100,000 B.t.u. per sq.ft. per hr. Very few, if any, industrial furnaces can produce heat at this rate.

Summary

While all the recommendations differ in details, they are reasonably consistent in calling for a slow heat input in the sub-critical temperature range, especially at temperatures below 1200° F.

This information has been of considerable value to the shipyard in the development of its present forging practice.

By Walter G. Patton
Experimental Laboratory
Climax Molybdenum Co. of Mich.

Mechanical Properties of NE, S.A.E. and Other Hardened Steels

One approach to this problem is to study tensile test data. Of course, it is not argued that the tensile test is the *whole* story; hardenability, wear resistance, high and low temperature properties, machinability and general service characteristics still have to be considered in any problem of substitution. However, tensile properties are the *first* consideration of both the metallurgist and the designer. Once satisfied as to acceptability of tensile properties, the metallurgist can take the next indicated step and compare the hardenability of the steels. The third step is, of course, to make test parts and watch the results in service. Finally the steel is put into production.

THE National Emergency steels are now in their second year. Hundreds, even thousands, of heats of low alloy steel whose composition falls within NE specification limits have already been produced. On three occasions, the compositions of these "lean alloy" types have been modified to accommodate critical alloy shortages, or meet current problems associated with the supply of scrap. There can be no guarantee that additional changes will not be necessary in the future.

It is therefore a timely question to ask: "Is there anything we can learn from past experience with NE steels which will help to simplify the changes future conditions may dictate?" And: "Is there adequate support for the proposition that steel producer, consumer's metallurgist, the specification writer, and the designer — as well as the purchasing department — can all feel on safe ground in accepting these new analyses?"

These questions about NE steels are frequently asked:

1. What is the probable range of tensile properties of individual NE steels?

2. How does this range compare with the range for S.A.E. steels?

3. What is likely to be the range of properties of any new NE steels which may be promulgated on the assumption that steels of equivalent hardenability are interchangeable for many applications?

One of the present difficulties is that the first step — the accumulation of tensile tests and their study — takes too long. If it can be shown that all fully hardened steels tempered to strengths less than 200,000 psi. are closely comparable, the introduction of a new steel can go forward promptly. If tensile properties fall within predictable statistical limits, it will no longer be necessary to plot and average data from many heats in order to satisfy an engineer that a new steel will develop the same tensile test relationships as the old. Moreover, if a similarity of tensile properties of fully hardened steels can be established, designers and specification writers, who have long been taught that each of the low alloy steels has unique and quite inflexible properties, may be willing to take a more generous viewpoint, either toward the present NE list, or other low alloy steels yet to be formulated.

It is undoubtedly true that the war effort can be expedited if simple changes in the chemistry of alloy steels can be accepted quickly rather than resisted until large amounts of test data become available. Considerable burden will be taken off both steel producers and metallurgists if critical alloy shortages and scrap problems can be eased from time to time without inciting misunderstandings between metallurgists, government inspectors, and specification writers.

Correlation of Tensile Tests

Study of a large number of tests of the new NE and the older S.A.E. steels demonstrates conclusively that the new steels have, on a basis of tensile tests up to 200,000 psi., behaved no differently than the S.A.E. steels. When fully hardened, NE steels offer the same combinations of strength and ductility at the same hardnesses as the steels they are replacing. Variation from heat to heat of the new steels is no greater than for the S.A.E. steels. The frequency with which the fully heat treated NE steels fall within a narrow, well-defined property range is comparable for S.A.E. and NE steels.

In short, the fully hardened and tempered NE steels are not distinguishable from S.A.E. steels, as far as tensile properties are concerned, when the steels are fully heat treated to strengths less than 200,000 psi. (At strengths above 200,000 psi. the relative positions are not yet clear but the present confusion may be due not so much to differences between steels as to difficulties in testing hard metal, and our present inability to control, at will, residual stresses in the test piece.)

The evidence sustaining these conclusions is summarized visually in Fig. 1 to 5, one of which is reproduced at large size for clarity in reading, the others being reduced somewhat yet still large enough to support the argument that follows.

Differences in the respective types of S.A.E. and NE steels will undoubtedly be discernible in actual service, but it is impossible to predict from the usual laboratory tests what these differences will be, regardless of the amount of testing that is carried out. This fact is often overlooked – in truth, not generally recognized.

The method used to correlate the tensile properties of 409 tests of 180 heats of steel was a familiar one. Essentially, it consisted of plotting tensile strength against yield point (as measured by the drop of beam), elongation, reduction of area, Brinell hardness, and Izod impact. Colored pins with special markings were used to distinguish the several types of steel.

The table lists the steels examined and the number of heats and tests plotted. More than half were uninoculated NE steels. An additional 50 tests of inoculated steels (treated with special addition agents) are included in the photographs, but their significance will be left to those in a better position to appraise their meaning. The remaining 140 tests were made on S.A.E. steels, supplemented by a few analyses close to standard S.A.E. ranges. These steels embrace practically all the heat treating grades available to industry today, as well as a few compositions not currently obtainable regardless of priority rating.

In the beginning, all data were restricted to tests made in the laboratories of Buick Motor Division of General Motors, Electro Metallurgical Corp., Republic Steel Corp., and United States Steel Corp. Data were further limited to steels treated in slightly larger than tensile bar size (0.525 in.). Tests on steel treated as 0.525-in. bars account for half the data used.

Once the scatter pattern was established for steels treated in 0.525-in. size, similar data were plotted for steels treated in 1-in. section. These data originated principally with the same four sources but there were a few additional contributors. The plots were found to coincide as to shape, frequency and range with the results for steels treated in 0.525-in. section so the informa-

Summary of Tests Plotted in Fig. 1 to 5

NE Steels			S.A.E. and Allied Steels			Inoculated Steels		
Alloy	Heats	Tests	Alloy	Heats	Tests	Alloy	Heats	Tests
8233	5	17	1045	1	2	1040-45	9	14
8245	3	8	1340★	18	40	1340	14	19
8339	8	21	2345	2	2	4042	1	2
8442	10	24	3150	2	2	4120	1	1
8447	4	9	3250	2	2	5045	1	1
8547	4	10	3440	2	2	8339	1	2
8630	10	37	4000	10	26	8442	4	9
8739	9	30	4130	5	5	8630	1	1
8744	4	12	4140	7	10	5040	1	1
8749	5	17	4300	3	3	Total	33	50
8949	8	21	4640-50	5	11			
9430	1	6	5040-50	2	2			
9440	1	7	5140-50	4	4	Grand total	180	409
Total	72	219	6150	9	12			
			N.A.X.	3	17			
			Total	75	140	★Also containing molybdenum		

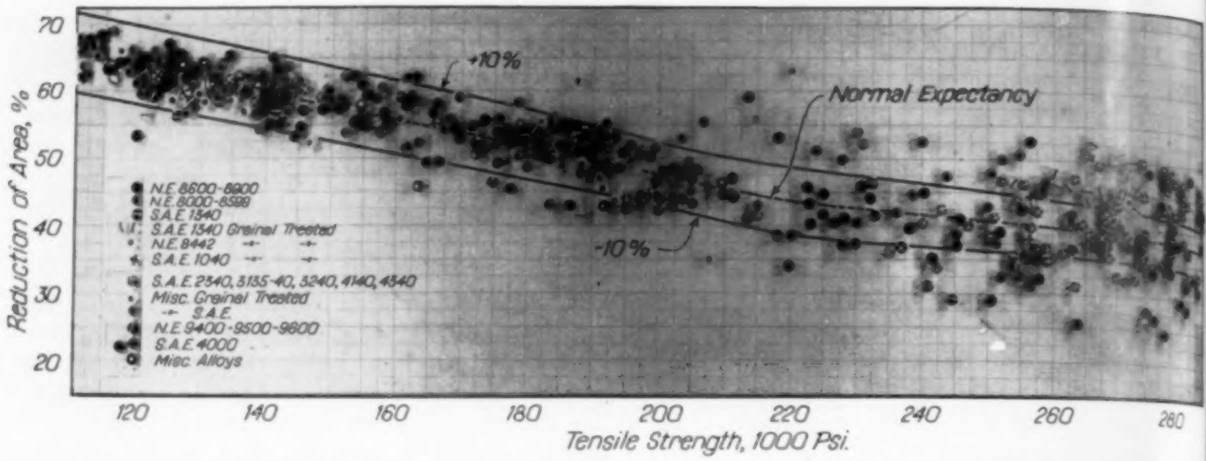


Fig. 1 — Tensile Strength Vs. Reduction of Area for 180 Heats of Low Alloy Steel Conforming to Most of the Common Specifications. Carbon contents: 0.30 to 0.50%; fully hardened and drawn to the indicated tensile strengths. No steel has ductility superior to others at strengths between 110,000 and 200,000 psi.

tion was consolidated on the basis that steels containing 0.30% carbon and upward, except in the case of very low alloy content, may be considered on an equal basis when treated in sections up to 1 in. At least, it can be said that any evidence of failure to harden throughout the section is not apparent from tensile data.

This method of handling the data was beneficial in several ways: First, the variations due to differences in laboratory technique were minimized; second, all steels could be regarded as fully hardened; and third, a more representative number of steels could be included.

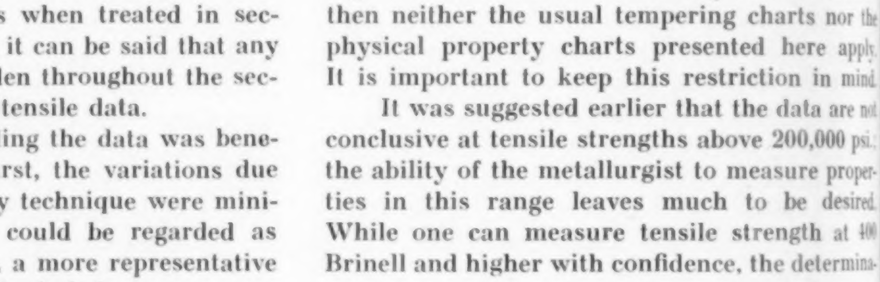
Limitations

The accompanying charts are not guides to heat treatment; the tempering temperature required to produce a certain tensile strength is not shown for any steel. Like a mortality table, the figures apply to low alloy steels *as a group*, and not to individual heats of steel. More specifically, the accompanying charts describe the *range* in which the properties of a given heat are likely to occur when the steel has been fully hardened and drawn to a given tensile strength.

It is necessary to describe a rather practical limitation of the data: When steel fails to harden fully on quenching, it will not respond to tempering in the same manner as fully hardened steel; then neither the usual tempering charts nor the physical property charts presented here apply. It is important to keep this restriction in mind.

It was suggested earlier that the data are not conclusive at tensile strengths above 200,000 psi.; the ability of the metallurgist to measure properties in this range leaves much to be desired. While one can measure tensile strength at 400 Brinell and higher with confidence, the determina-

Fig. 2, below — Izod Tests Scatter More in Absolute Value at Low Strengths Than at High



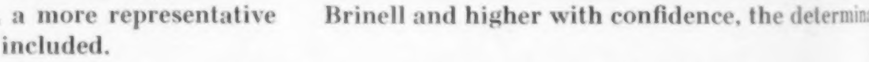


Fig. 3, above — Elongation of Heat Treated Steel, When Plotted Against Tensile Strength, Falls Within a Narrow Band, Showing Little to Choose Between Various Alloy Steels in This Respect

tion of yield point, elongation, reduction of area and Izod impact is subject to errors in testing that do not bulk nearly so large when tests are conducted on softer material. The situation is further complicated by the fact that a difference, for example, of 10 ft-lb. Izod on 60 ft-lb. material (having, say, 150,000 psi. tensile) means a variation of 16%; if the same steel is heat treated to 250,000 psi. tensile an impact figure of 10 ft-lb. would not be unusual, yet a change of 10 ft-lb. is then equivalent to a 100% variation.

Fig. 4, below — Tensile Strength is Less Than 500 (About 480) Times the Brinell Hardness in All Thorough-Hardened Steels Tempered in the Range 250 to 450 Brinell

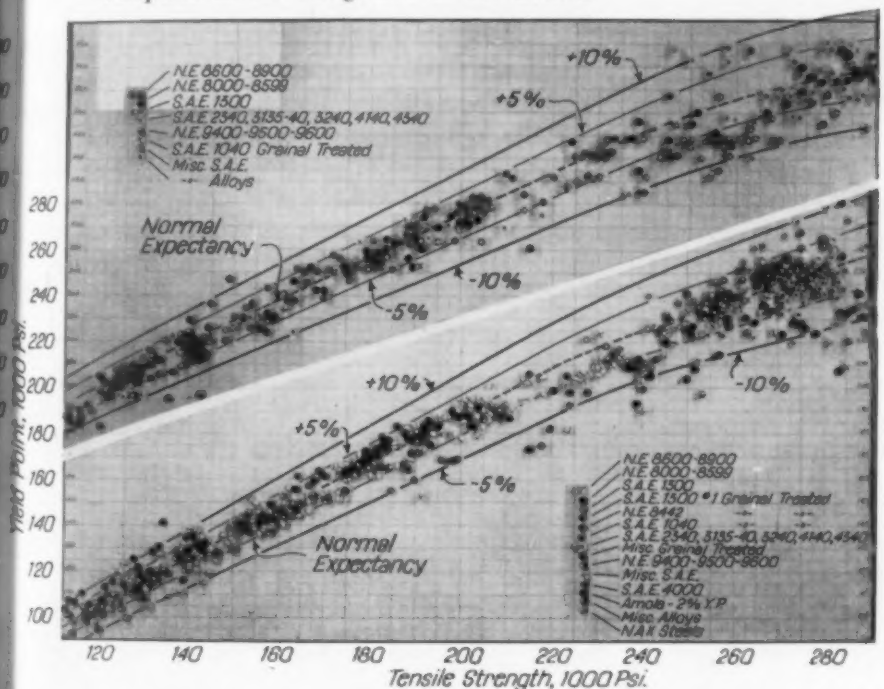


Fig. 5, above — Yield-Tensile Ratios of Medium Carbon Alloy Steels (Heat Treated to 110,000 to 200,000 Psi.) Are Independent of Alloy Content

The author does not feel qualified to pass judgment on the significance of tests when steels are treated above 400 Brinell. The curves beyond 200,000 psi. tensile should, therefore, be regarded as tentative — something to use until a better yard-stick is available, following the accumulation of data by more closely controlled tests.

General Observations

As shown in Fig. 1 to 5, for each cluster of pins representing steels treated up to 200,000 psi. tensile, there are for each type just about as many points above the center of the band as there are points below a theoretical center line. This observation applies both to S.A.E. and NE steels. Similarly, for every test category, the spread in test results from heat to heat of the same steel is about the same as from alloy to alloy.

It is possible to make two basic assumptions in interpreting such results. One can assume, for example, that the fully hardened steels are actually identical and the fluctuations in properties are due to variations in testing. (Incidentally, there is practical evidence to sustain such an assumption.)

On the other hand, if we insist that the test results truly reflect the properties of the steels, we must reason that the normal variations in the tensile properties of the NE steels are no greater — or no less — than for S.A.E. steels.

Whatever interpretation of these data is acceptable, these conclusions seem inescapable:

1. As reflected by tensile tests of fully hardened steels, the *apparent* properties of low alloy steels are subject to some fluctuation, regardless of composition.

2. The amount of such fluctuation for the several steels is reasonably uniform. The variations from heat to heat for any single one may run from ± 5 to $\pm 10\%$ depending upon the hardness of the steel and the type of test. (Normal fluctuation for impact tests made on low strength material is $\pm 20\%$ or more.)

This amount of variation may be expected of fully hardened steels. Even broader variations can be looked for if heat treatment has been faulty and the steel failed to harden throughout the section.

From these general observations, the discussion proceeds to a consideration of specific tests. Reduction of area will be mentioned first, because many testing engineers believe that good "toughness" is associated with high ability to deform.

Ultimate Strength Vs. Reduction of Area is shown in Fig. 1. It is apparent that below 200,000 psi. tensile, a range of $\pm 10\%$ includes nine-tenths of the test results; a range of $\pm 5\%$ is broad enough to include about two-thirds of the results

reported for all the low alloy steels containing from 0.30 to 0.50% carbon and heat treated to less than 200,000 psi. ultimate. However, the results of reduction of area tests on the same kind of steels heat treated to high tensile strength are likely to vary over a greater range than almost any other standard test, and any conclusions that may be drawn would be strictly tentative.

1. The normal reduction of area line follows the same general contour as the elongation curve (Fig. 3), except that the slope is less and there is no marked evidence of curvature in the band of plotted results below 200,000 psi. tensile.

2. Below 200,000 psi. tensile, no alloy combination appears to have a consistent advantage over any other type of alloy steel.

3. At tensile strengths above 200,000 psi. scattered results tend to vitiate any conclusions.

Tensile Strength Vs. Elongation

(See Fig. 3, page 728)

1. From 110,000 to 200,000 psi. tensile, the normal relationship of elongation to tensile strength can be represented by a smooth curve. Beyond 220,000 and up to 290,000 psi., the decrease in elongation appears to be comparatively small.

2. At all tensile strengths, elongation figures vary over a range of ±10% or more. At tensile strengths up to 200,000 psi. about 80% of the results for all steels fall within this ±10% range.

3. At less than 200,000 psi. no alloy combination gives consistently higher elongation than any other; the variations in results reported for any one alloy steel were as great as the range for all the steels tested.

Ultimate Strength Vs. Yield Point

(See Fig. 5, page 729)

1. Up to 200,000 psi. the relationship of yield strength to tensile strength may be approximated by a straight line. Two out of three heats fall within a range ±5%.

2. There is no apparent difference in the frequency with which S.A.E. and NE steels approach a normal line at the center of the band.

3. Above 200,000 psi., the normal expectancy or average line falls off in slope, indicating a decrease in the yield-tensile ratio for the harder steels.

4. Yield values fan out to a considerable extent above 200,000 psi., reaching a maximum scatter at high tensile strength. Whatever the explanation of this condition — favorable or unfavorable stress conditions, difficulty of making accurate yield point determinations, possible consequences of retained austenite in the steel — the variations are seldom greater than ±10%.

5. For an unexplained reason, between 210,000 and 260,000 psi. tensile, the majority of yield points plotted fall *below* the average line which fits all other data.

6. Up to 200,000 psi. no single alloy combination gives values that are consistently above or below normal expectancy.

When all these factors and conditions are considered, the hazards may well be imagined of attempting to judge from a single test, or even a few tests, the yield-tensile characteristics of an S.A.E. or NE steel which is to be used at 500 to 600 Brinell (250,000 psi. and upward). Based on the evidence at hand, it seems possible that where deoxidation or stress conditions are favorable, practically any of these steels could, under some test conditions, give a high yield-tensile ratio at high hardness and tensile strength. The converse would also be true. Whatever the role of composition, other factors are involved in measuring yield point at high hardness which may exert as strong an influence as the composition.

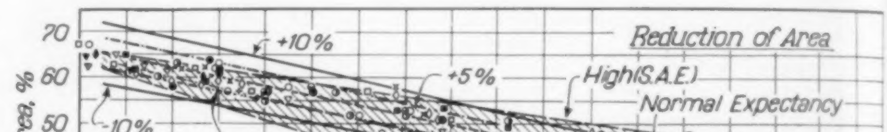


Fig. 6 — Check Chart Showing Relation Between Tensile Strength and Reduction of Area of Older Standard Steels (Average Results Published in Producer's Catalogues) and the Normal Expectancy and ±5% and ±10% Lines Determined in Fig. 1 for Original Tests. Shaded area is range given in S.A.E. Handbook

Tensile Strength Vs. Brinell Hardness

(See Fig. 4, page 729)

1. As in the case of yield point, the relationship of hardness to tensile strength is approximately a straight line up to 200,000 psi. Above 250,000 psi. the trend is best represented by a curve.

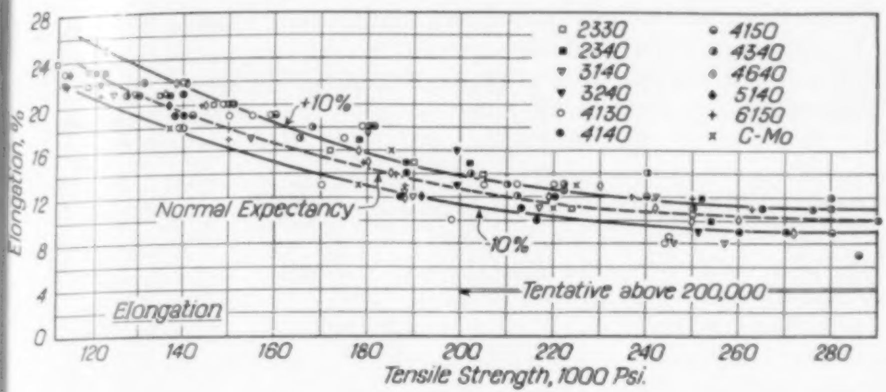


Fig. 7 — Check Chart Showing Relation Between Tensile Strength and Elongation in 2 In. Plots are published data; lines are from Fig. 3 representing original tests

2. Below 250,000 psi. tensile, the normal ratio of tensile strength to Brinell hardness is less than the 500 to 1 ratio which is commonly used; above 250,000 tensile, the ratio is slightly more than 500.

3. Except at very high hardness, a variation of ±5% will include four out of five Brinell readings taken at any tensile strength and regardless of the composition of the steel.

4. There is a tendency for Brinell readings to fan out at high tensile strength, but this tendency is not as great as it is in the case of yield point measurements.

5. There is no indication that the relationship of Brinell hardness to tensile strength is altered in any manner by alloy content.

Tensile Strength Vs. Izod Impact

(See Fig. 2, page 728)

So far as this particular study is concerned, the results of Izod tests are less numerous and conclusive than for any other test. Since only fragmentary data are available in the literature today, it is hoped interest in obtaining such information may be stimulated. Conclusions which may fairly be drawn are:

1. Izod impact is the only property measured by the five standard tests which shows greater variation of results at low tensile strength than at high tensile strength. It is believed this behavior can be attributed largely to the mechanics of the test, rather than to variations inherent in the material.

2. Below 200,000 psi. tensile, a spread of ±20% is insufficient to include more than two-thirds of all reported results. This is not a satisfactory background for judging the impact properties of a particular heat of steel. When it is recalled that the plotted results are averages for three tests, the possible range of individual impact results can be imagined.

3. Based on incomplete data, at strengths below 200,000 psi. no alloy combination plotted thus far appears to enjoy consistent advantages over other types of fully hardened steel.

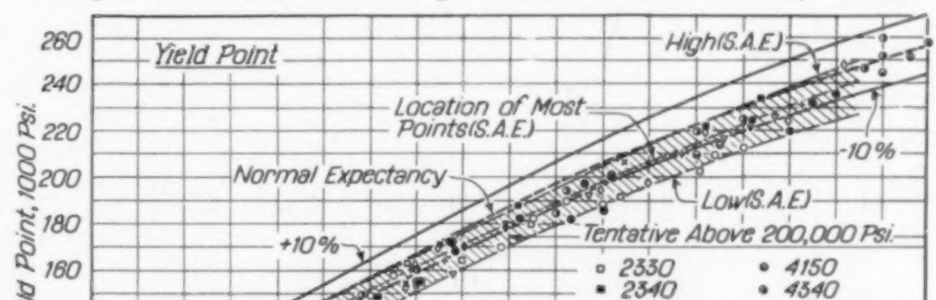
4. A drop in impact when tempered in the blue brittle range (300 to 700° F.) is not indicated by the present data. Assuming that such a phenomenon actually exists, it would not be shown in these charts because of the method of plotting.

5. The results in this category are not conclusive. Much additional work remains to be done in determining the possible effects of specific alloying elements on the impact properties of fully hardened steel.

Normal Expectancy Curves Vs. Published Data

As a check on the normal expectancy curves developed in this study, and shown as the median lines in Fig. 1 to 5, data on several S.A.E. steels were taken at random from the property charts and tables compiled by Jos. T. Ryerson & Son,

Fig. 8 — Check Chart Showing Yield-Ultimate Relationship. Manufacturer's catalogues (and S.A.E. Handbook) give values 5% less than actually encountered



U. S. Steel Corp., International Nickel Co., Bethlehem Steel Co., and Climax Molybdenum Co. Twelve S.A.E. steels were used and 108 points were plotted. The results of this comparison are given in Fig. 6 to 9 inclusive.

These published elongation and reduction of area data at tensile strengths under 200,000 psi. fit the lines from Fig. 1 to 5 reasonably well. Beyond 200,000 psi. the published values for reduction of area are generally lower than the new data.

Published data for yield point parallel, but are consistently 5% lower, than the normal expectancy curve developed in this study. The majority of published impact figures are lower than the actual test results, but as already mentioned, the evidence with respect to impact strength is not conclusive.

It appears that yield point and Izod values published by steel makers and sellers have been on the conservative side. A mistaken tendency of some users to employ published data as a basis for preparing *minimum* specifications may account for some of the difference between published and reasonably expected values.

As a further check, the property charts in the Society for Automotive Engineers' Handbook have been placed on these same charts in cross-hatched areas. The S.A.E. charts are also based on various published data rather than on original test results.

Discussion of Results

1. Work of Janitzky and Others

The contention that fully hardened, low alloy steels give strikingly similar combinations of mechanical properties after they are drawn to a given tensile strength is not new. Janitzky observed this similarity a number of years ago; his discussion of the subject will be found on page 515 of ⊛ Metals Handbook, 1939 edition. Janitzky's work failed to receive the attention it undoubtedly deserved, possibly for some of the following reasons: *(a)* The data are based on a relatively few heats of steel; *(b)* the curves for all steels fall so nicely in line they do not, at first glance, appear to coincide with normal commercial experience; *(c)* like the present study, the record is inconclusive above 400 Brinell; *(d)* Janitzky's report deals with steels which are currently under strong priority restrictions.

Further support of the contention is found in the circumstance that S.A.E. has abandoned its former practice of including tensile charts in its Handbook, on the ground that such charts are needless, if not actually misleading. The editor of the ⊛ Metals Handbook has taken similar action.

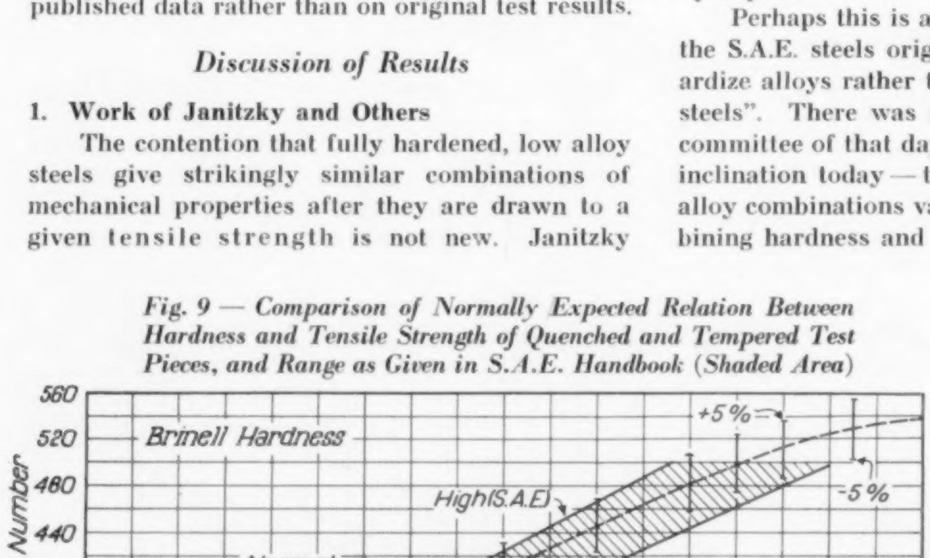
2. Prejudice Against New Steels Understandable

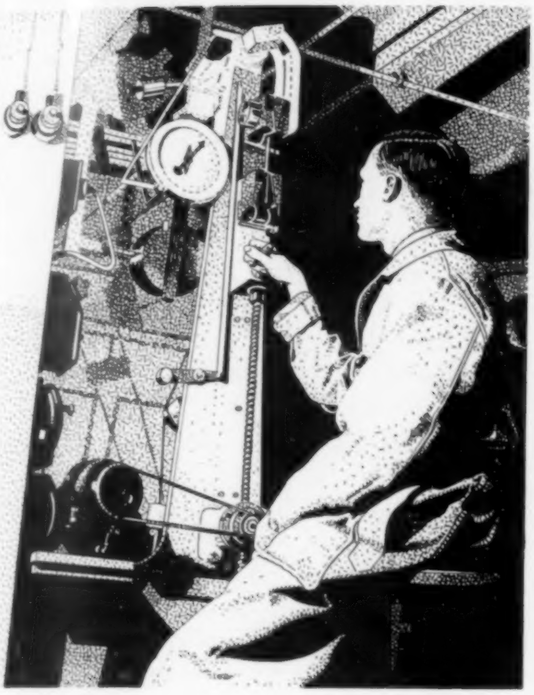
For a number of years, the S.A.E. steels have served industry most acceptably. In fact, their performance has been so outstanding as to confer on these steels, in the minds of many, the distinction of being the only alloy combinations that could possibly give such high properties in day-by-day use.

Perhaps this is a good time to emphasize that the S.A.E. steels originated as an effort to standardize alloys rather than a move to create "super steels". There was no disposition by the S.A.E. committee of that day -- there would be even less inclination today — to ascribe to these particular alloy combinations vastly superior talent for combining hardness and toughness in fully hardened steel. The alloy content was prescribed then, as now, primarily to produce hardenability.

The reputation for superiority enjoyed by S.A.E. steels has been enhanced by the fact that in the early days fully hardened alloy steels were often compared with shallower hardening steels — to the constant disadvantage of the latter. A repetition of such "loaded" comparisons is not likely to be repeated in the light of our present knowledge concerning hardenability.

Fig. 9 — Comparison of Normally Expected Relation Between Hardness and Tensile Strength of Quenched and Tempered Test Pieces, and Range as Given in S.A.E. Handbook (Shaded Area)





In considering the possibility of developing steels with superior combinations of tensile properties, it may be well to remember that the NE steels are, after all, 97.3% iron; the remainder of the alloy consists, essentially, of "impurities" in the form of alloying elements. The function of alloy in such steels is to influence phase changes. All the steels in the present study are believed to be fully hardened and the important function of the alloys was satisfied when the steel was quenched. That is to say, the steels were fully hardened insofar as this fact is revealed by hardness and tensile testing.

All the steels were subsequently tempered. The microstructure in all cases would therefore be tempered martensite.

When it is suggested that all fully hardened steels — S.A.E., NE, and others — have similar properties below 200,000 psi., this is only another way of saying that tempered martensite with a small percentage of alloy and tempered martensite *without* this small amount of alloy have about the same tensile properties. After tempering at the temperature required it would be remarkable if the steels did not have similar properties! Above 200,000 psi. tensile, another important factor — stress — enters, and may even dominate the picture. This chapter of the book of metallurgy has not yet been written.

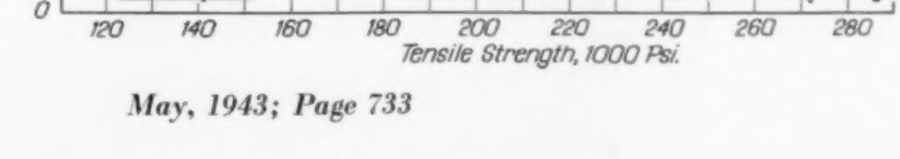
Looking Forward

It seems clear that, with respect to fully hardened steels, tensile testing has just about reached the limit of its ability to teach us useful things about the properties of low alloy steels softer than 400 Brinell. Regrettably, above 400 Brinell, such tests are not accurate enough to teach us many of the things we need so much to know.

The graphs (Fig. 6 to 10) are intended to serve as a check-chart. Individual tensile tests of NE steels treated to less than 400 Brinell may be compared with the bands shown here until it has been concluded that the results are sound. Later on, it may be possible to eliminate some tensile tests, substituting for them a carefully made hardness determination (or determinations) and estimating other tensile properties from these charts. Some use of the data for steels harder than 400 Brinell may be found, always keeping in mind the limitations of tests conducted at high strength.

If unnecessary tensile tests could be eliminated, it would greatly speed the adoption of new alloy steels that are forced on industry by war conditions. Also, this would release much needed metallurgical talent for other important work. Many metallurgical departments could certainly spend, at a profit to all concerned, more effort on problems like machinability, stress distribution, surface finish and engineering design, and less effort pulling tensile bars, especially since the information finally obtained can be estimated accurately, once there is assurance the steel was fully hardened on quenching. No doubt, specifications will continue to insist on many unnecessary tensile tests, but it is pleasant to reflect that the future may make it possible to direct much of this effort into more productive channels.

Fig. 10 — Check Chart of Izod Tests, as Related to Tensile Strength



Critical Points

By the Editor

To ABERDEEN Proving Ground with a group of technical editors, where Colonel Eddy, director of the proving center, exhibited the performance of the full range of American guns, motorized equipment, anti-tank and anti-aircraft artillery — in many instances paralleled by exhibitions of captured enemy materiel. Only generalities can be reported, but the most general would be a solid pride in the quality and performance of American equipment — a feeling shared by both American and British troops, as we were assured by General BARNES, Chief of the Technical Division, Army Ordnance, just returned from the Libyan and Tunisian fronts.

American ordnance tested in Africa

Reminding us that this unfailing performance could only be achieved by rigid adherence to inspection standards that might, at times, seem needlessly high, he said that troops use our equipment with the greatest enthusiasm, and that this utmost confidence in their weapons is of paramount value to morale. . . . .Recent improvement in all this materiel is exemplified in three successive embodiments of the 0.30-caliber rifle, and is instantly apparent when you handle and fire the guns yourself. The Springfield rifle of 1914 was a good rifle — still is — but the Garand hits a harder blow and is almost the equivalent of an old machine gun, whereas the new 0.30-carbine increases the fire power still further, is simpler to manufacture and weighs little more than a target rifle. To this demilitarized observer it is the answer to the sweating infantryman's prayer. . . . . German and Italian equipment is well made and very serviceable — which is more than can be said for Japanese arms, whose limitations are largely responsible for the extraordinarily high ratio of dead Japs to dead whites in Guadalcanal and New Guinea. . . . General BARNES reported nothing but praise from MONTGOMERY'S army for the American jeep, the light tank, the M-3 medium tank that stopped Rommel just short of Alexandria, and the M-4 tank that routed him at El Alamein. From what The EDITOR has been able to see and to read in the papers, however, it would seem that, in the eternal battle of guns against armor, the guns appear to be getting the upper hand of the land battleships. After all, a tank is merely a highly mobile gun platform, armored to give maximum protection to the crew and mechanism. Yet there is a practical limit to the weight of armor that can be moved over soft ground and ordinary bridges, as is proven by the U. S. heavy tank a year ago, and by the German Mark VI tanks which were to be such-a-much. This weight of German armor (4 in.) can be defeated by our high velocity 3-in. and 105-mm. guns, and these guns with their immense hitting power and long range are readily mounted and served on a fast-moving tank chasis if the latter is not burdened by more than enough armor to withstand shell fragments and machine gun fire. (Likewise high explosive shells from these guns are terribly effective against infantry, even in slit trenches, destroying life by blast and shell fragments within 30 yd. of an overhead burst.) While tanks, of the best, will undoubtedly carry the battle to the enemy, it would not be surprising to find the battle of Europe decided by far greater numbers of heavy guns mounted on motor carriages, constantly moving up to support the invading infantry.

Mobile gun vs. the tank

ATTENDED, during the February meeting of the Mining Engineers in New York, a reunion of a pre-depression Three-Hours-for-Lunch Club, and so arrived too late to get a seat at a

discussion of boron as an alloying element in steel. Snatches heard from standing room out in the hall, plus a report from one of *Metal Progress'* spies, minus deletions by censorship, gives this result: The mystifying vapors that recently have surrounded "intensifiers" are evaporating, and boron appears as another hardener — very powerful, but having the characteristic effects of other alloying elements on the S-curve — and operates on most types of steel except perhaps on the high carbon hyper-eutectoids. A small part of the extra hardenability is admittedly due to the grain-coarsening effect of boron as the annealing or normalizing (or shall we adopt the ungainly word "austenitizing" or "austenizing") temperature increases a little above the upper critical. However, the main effect due to the *form* that boron takes in the structure is still controversial, for there is only a few thousandths per cent there — in fact, analysts and spectroscopists are not too certain of the results. The chemists are pinning their hopes on a reagent named quinalizarine (pronounced with a lilt like Queen Elizabeth). Owing to analytical uncertainties, bold would be he who correlates hardenability with actual boron content, since the only reliable data are related to "amount of boron added to the melt". This addition, as is known to all who are in contact with the leading alloy producers, can be made with any one of several trade-named materials (if the steel maker does not want to take a chance with simple borax) and each producer believes his method is best. All agree, however, that it is a nifty element!

Boron—a nifty alloy for steel

TO BENDIX, on Passaic's frozen meadows, in a huge bus crowded with aircraft workers, some violently discussing the inadequacy of their Union's protective measures and the unfairness of some Company rules, methinks unmindful that a good job well done would remove completely any conflict. Others commented disdainfully that "These girls will never get any mechanical sense" — wishful thinking, for Doc WOLDMAN told me later that some women are producing more on automatics and earn more bonus than ever a man did.....NORMAN WOLDMAN, chief metallurgist of Bendix's Eclipse-Pioneer Division, makers of everything that goes into an aircraft structure besides engine and pilot, commented on the undoubted importance of cast magnesium (present and future) for parts of modest duty, now that Dow's new modified chromate dip has proved such a good corrosion resister, and now that ingot is so abundant and foundries so new and numerous. In all aircraft instruments and auxiliaries *weight* must be a minimum; other necessary properties of the materials (sometimes in perplexing combinations) often complicate the selection, such as strength, magnetism or lack thereof, low inertia, constant elastic action, wear resistance. ....Aircraft fitments have adopted few of the substitutions forced on many other metallifactures, and for several reasons: The designing engineers bear the responsibility rather than the metallurgist and, not being materials experts, their first choice is for the "old reliable". Secondly, once a part is in production it takes months to make it of new materials and run life tests, and more months for the Air Forces to make model tests. Thirdly, some substitutes are harder to get than the older analyses, what with the aircraft industry's high priorities on "standard" steels.

Materials for aircraft instruments

OUT TO Packard, in Detroit, now building nothing but V-12 engines, one style for American PT boats and another style for aircraft (the liquid cooled Rolls Royce). Guided by GEORGE BIDIGARE to the heat treat, half a mile away, and marveled at the disparity between the magnitude of the plant and the price of Packard common on 'change — undoubtedly an illustration of the dictate that no one should get rich out of this war....One orderly section anneals and nitrides the crankshaft. This is a 4-ft. long forging of "VCM" analysis — 0.35% C, 0.65% Ni, 1% Cr, 1% Mo — with ultimate of 120,000 psi., elongation 16% in 2 in., 55% reduction of area, 269 to 293 Brinell hardness. Each forging has a 6-in. tonghold from which a test bar is machined; one in eight is turned to 0.450 in. and goes through all heat treatments before testing. Cranks are annealed, once after rough machining and again after semi-finish machining — to relieve internal stresses and promote dimensional stability. Bearings are finally ground

Nitriding Rolls Royce crankshafts

0.0005 oversize and the whole shaft except a nickel-plated flange nitrided under Westinghouse covers. Nitriding cycle takes 84 hr., of which about 62 is at heat, during which a case 0.020 in. deep is produced, testing 88½ to 90 on the Rockwell 15-N superficial scale. The accompanying round test pieces must measure Vickers 400 hard after a flat 0.012 in. deep has been ground. A V-notch 0.130 in. deep is ground, and the bar tested in an Izod impact machine. Specified minimum energy absorption: 55 ft-lb.....As pointed out by BIDIGARE, one advantage of this heat treatment is minimum warpage. Shafts are pivoted on No. 2 and No. 6 bearings and center main bearing must run out less than 0.005 in.

QUENCHING from *minimum* hardening temperature is the rule in Packard aircraft heat treatments, since this minimizes warpage and retains very little austenite in the high alloy parts. Even though a surprising number of engines are being made, MUIR FREY, aircraft metallurgist, said that the volume of parts to be hardened is rather small, in terms of automotive mass production. Single purpose furnaces are out of the question. Shortages in steels prevent any large bank of parts, and they have to be handled a tote-load at a time as they come from the machine lines. How adjust the continuous hardening furnaces and the protective atmospheres to the needs of each analysis and each shape? BILL GRAVES, Packard's chief metallurgist, and JOHN DOW, Holcroft's furnace engineer, found that all the parts could meet specifications if oil quenched from 1510° F., and so the furnaces are run. Considerable variation exists in the quenching routines, however. Many gears are hooked out a side door and quenched in presses. Tray-loads of other parts are lowered by elevator into the oil tank from a gas trap at the end of the furnace. Most of these parts are in the oil about 15 min., but some, like connecting rods, are time quenched — removed smoking and flashing after a short but measured time — in order to avoid cracking and excessive warpage.

Uniform furnace, varying quenches

EVEN MORE surprising is the ability to harden all these steels from a single protective atmosphere. Periodically small rings and bars, cut from the principal analyses going into these aircraft engines (carburized or not, as the case may be) are put through on a regular tray. Test for surface decarburization is made by noting the difference in Rockwell superficial hardness (15-N scale) of the hardened surface and after 0.001 in. is ground off. This difference must not be greater than −1 on case-hardened parts. Similar tests for carburizing action are made on 0.15% carbon pieces representing the core. The 15-N hardness value on these must not be more than +2 its original value. The atmosphere that does the trick is made by mixing 9 volumes of "semi-cracked gas" with 14 volumes of "charcoal gas" from a Holcroft converter, the exact proportions and the dew point (moisture content) being adjusted if the test rings indicate unwanted surface changes. The semi-cracked gas is made by partial combustion of natural gas; a portion of the gas is passed through pots of incandescent charcoal and emerges as "charcoal gas".....Packard-built Rolls Royce engine parts coming from the quench look like weathered bronze. There is no "scale" that can be scratched off, the dark coloration is strictly superficial and disappears in shot-blasting (peening), buffing, lapping or other final finishing.

A neutral atmosphere for hardening

CONSIDERED certain technical aspects of the World Revolution, in brief talks to various Chapters, and prophesied that the supply of ores and other raw materials would have commanding influence in tomorrow's metal economy. The enormous drain on the Lake Superior open pits means an early exhaustion of that already over-worked bonanza of iron ore; this will bring in its wake profound dislocations and modifications of the steel industry, and an inevitable rise in true cost of steel. On the other hand, the veritably inexhaustible supply of sea-water magnesium presages its future importance. As to the other metals like manganese, chromium, copper and zinc, if America is wise we will import vast quantities of them, not only to get something in return from lend-lease, but to conserve our own expensive supplies against a future emergency — but how often has America been wise in such matters as foreign trade?

Future metal balance

Fatigue Failures in Common Machine Parts

By J. O. Almen
Research Laboratories Division
General Motors Corp.

A bolt or stud should be tightened to a load exceeding the maximum working load. When properly tightened against rigid members, a bolt or stud cannot fatigue because there can be no change in stress; the bolt load is static even though the load applied to the bolted member oscillates at high frequency from zero to a maximum. This rule must, however, be applied with caution because all bolted members are elastic in some degree and the design of the bolted members may be such that the applied load is greater than can possibly be supported by the fastenings. An exaggerated case of this kind is shown in Fig. 1 *(a)* in which the connecting rod bolts are excessively stressed in tension and in bending because the distance *L* from the bolt to the point *C* is small and, since the bolted parts tend to bend about the point *C* as a fulcrum, the tension and bending loads in the bolts are great. An improved design is shown in Fig. 1 *(b)*, in which the fulcrum point *C′* is further removed from the bolt and, therefore, the tension and bending loads are reduced. This is a case in which fatigue failure of one member is due to faulty design of another. We must remember that, like an aching tooth, the one that seems to hurt is not necessarily the one that should be pulled.

In an article in the February issue of this magazine the general problem of fatigue failure was discussed, and it was pointed out that in the great majority of cases failure starts at a surface where high tension stresses are localized. It was demonstrated that if such a surface were prestressed in compression the liability to such fatigue failure would be correspondingly lessened, a fact which is utilized in practice by peening the surface. Methods of doing this, and of estimating the resulting compressive stresses, were also outlined.

Bolt Failures

The fatigue vulnerability of bolts and studs has been discussed in many papers (listed in the excellent book by the Battelle staff on "Prevention of the Failure of Metals Under Repeated Stress") and the improvements resulting from reducing the diameter of the bolt body and from pressure rolling of the threads have been adequately recorded. Insufficient attention, however, has been given to fatigue vulnerability due to insufficient bolt tightness.

If the bolt in Fig. 1 *(b)* should fail by fatigue it could still not be charged to insufficient strength because, as stated above, if the initial bolt tension is less than the maximum external load the stress range under repeated loads is increased. Let us suppose that the bolt is tightened just enough to bring the surfaces into contact without appreciable tension. Under alternating stress the stress range would be from

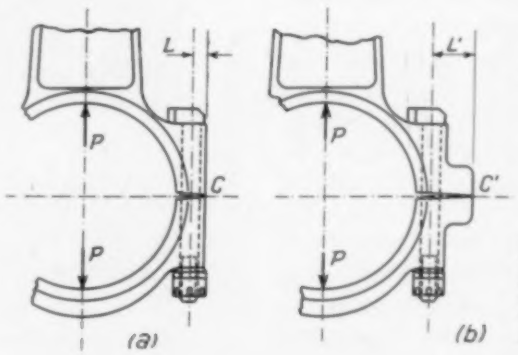


Fig. 1—Fatigue Failure of Bolt Due to Elastic Changes in Bolted Member Cured by Increasing the Effective Length L′, to the Right

zero to maximum and fatigue failure could only be avoided by greatly increasing the bolt strength. As the initial bolt tension is increased the stress range is decreased until it approaches zero when the initial bolt tension is equal to or greater than the maximum working load. This would illustrate a case in which a failure is not the fault of either bolt strength or design but is chargeable to bad assembly.

The vulnerability to fatigue as a function of bolt tightness is shown in Fig. 2. In the tests plotted all bolts were subjected to a cyclic tension load of 9210 lb. but were tightened to initial tensions of 1420, 5920, 7220 and 8420 lb. Fifteen bolts were tested at each of the three lower loads in order to establish the scatter band for this kind of specimen. Only two bolts were tested in which the initial tension was 8420 lb., one of which failed after 4,650,000 stress cycles and the second had not failed after 10,000,000. Bolts used in these tests were ⅜ in. diameter, accurately dimensioned and finished; threads were U. S. form, 24 threads per in. and ground to close limits.

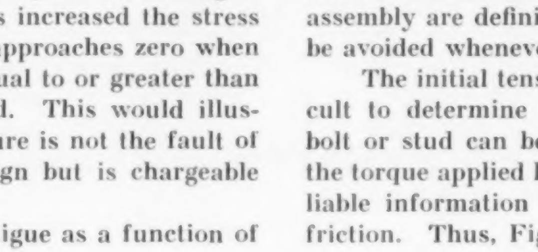


Fig. 2—Effect of Tightness (Setting-Up Tension) on Life of Bolt in Alternating Tension

The stress range to which these bolts were subjected is the difference between the initial tension and the maximum operating load; since it is known that the fatigue durability is increased as the stress range is decreased, we would expect results of the order that were obtained in the chart. All failures occurred in the threads except in a few cases in which the threads were rolled in a manner to pre-stress the roots in compression. In these rolled-threaded bolts the fatigue durability of the threads was increased sufficiently to cause failure in the shanks. When the surfaces of the bolt shanks were also compression pre-stressed by peening, the failures were again transferred to the threads but, of course, at prolonged durability.

These tests, therefore, also show that the fatigue durability of cut and ground screw threads can be increased by rolling and indicate that compression pre-stressing of the surface of pure tension members is effective in increasing their fatigue strength.

It is therefore evident that the fatigue strength of bolts and studs stressed in tension is dependent upon the *initial tension* applied by the nut, *plus* the elasticity of the bolted members. Therefore, washers, lock washers, gaskets and other units that add to the elasticity of the bolted assembly are definite fatigue hazards and should be avoided whenever possible.

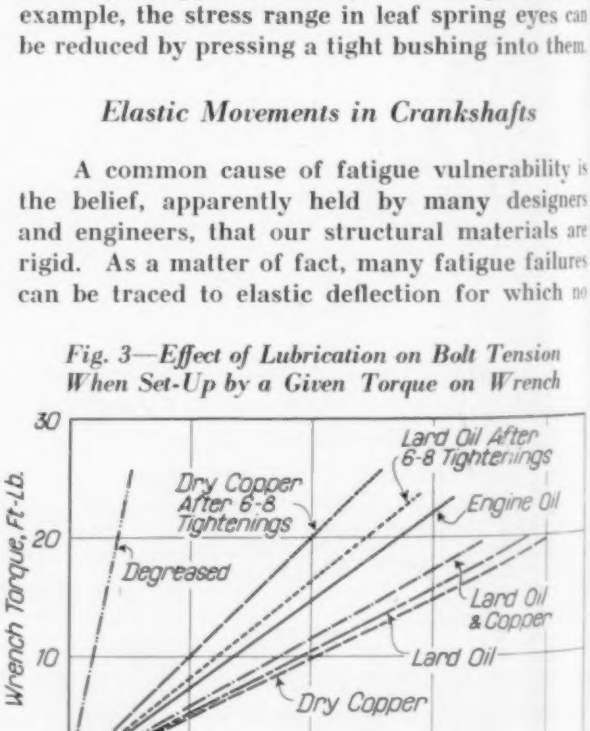
The initial tension applied by the nut is difficult to determine unless the elongation of the bolt or stud can be measured. Measurement of the torque applied by the wrench gives very unreliable information because of the variability of friction. Thus, Fig. 3 records tension measurements plotted against wrench torque in ft-lb. for $\frac{5}{16}$-in. bolts having 24 threads per in. It will be seen that the bolt tension varied as much as ten to one (1000%) for constant wrench torque depending upon the lubricant used; that is to say, a 10 ft-lb. torque puts a 200-lb. tension on a degreased bolt, and a 2000-lb. tension on the same bolt covered with lard oil. The mechanical efficiency of this bolt varied from 1 to 10%, as is shown in the chart.

Pre-loading of cyclically stressed members to reduce the stress range and thus to increase their fatigue durability is not restricted to bolts, but may be applied to many machine parts. For example, the stress range in leaf spring eyes can be reduced by pressing a tight bushing into them.

Elastic Movements in Crankshafts

A common cause of fatigue vulnerability is the belief, apparently held by many designers and engineers, that our structural materials are rigid. As a matter of fact, many fatigue failures can be traced to elastic deflection for which no

Fig. 3—Effect of Lubrication on Bolt Tension When Set-Up by a Given Torque on Wrench



allowance was made in the design. It has already been shown in Fig. 1 that elastic deformation of mating parts may be such as to concentrate the load in a small region.

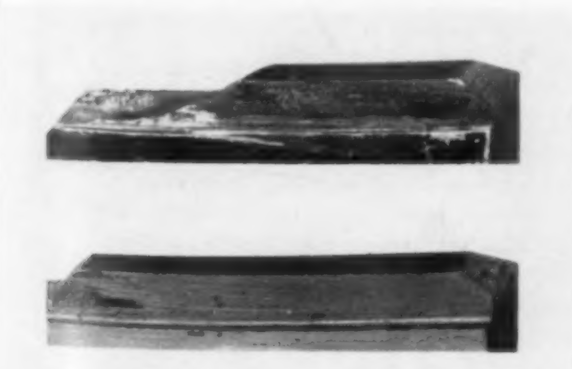
Under operating conditions a crankshaft may be so elastically deformed in twisting and in bending that the bearings are only partially effective in supporting the load. The bearings are frequently found to be plastically deformed or worn "bell mouthed" to accommodate the elastic gyrations of the crankshaft! Proper attention to this detail is likely to increase the size of the shaft to a degree where its unit working stresses are surprisingly low.

Elasticity in Gear Trains

Perhaps the most generally misunderstood of all machine elements are the several classifications of gears. As ordinarily designed there is only one thing certain about gears and that is that they will not function as intended by the designer! When laying out a set of gears on the drafting board, the mating gear teeth are represented by parallel straight lines but no matter how carefully the gears are cut and heat treated the mating teeth will never again be parallel except by accident — and then only through a small load range.

The nature of the contact between two mating gear teeth is influenced *(a)* by the elastic characteristics of the housing in which they are contained, *(b)* by the elastic characteristics of bearings by which they are supported, *(c)* by the elastic characteristics of the shafts upon which they are mounted, *(d)* by the elastic characteristics of the gears themselves, *(e)* by the accumulated dimensional errors in all the supporting parts as well as the errors in the cutting of the gears, *(f)* by the necessary and accidental clearances in the supporting parts, and *(g)* by the amount and nature of the warpage in heat treating — to give the metallurgist some of the responsibility.

Fig. 5 — Broken Tooth and Unbroken Partner That Prove the Trouble Was Due to Concentration of Load at Left End



The result of all this is that it is virtually impossible that the parallelism between mating teeth as visioned by the designer can exist in practice. If it should chance that two mating gear teeth are parallel at some load, they cannot be parallel at any other load because the elastic deflections of some of the supporting parts are not linear with respect to the load. As usually designed, the load on gear teeth is never uniformly distributed over the length of the teeth but is always concentrated toward one end. This localization of the load is shown in Fig. 4, which is a record of the contact impressions of gear teeth under load in a commercial gear box. Load localization cannot often be seen on examining a gear that has been in service because each tooth of each gear usually makes contact with all of the teeth in the mating gear, and the summation of all contacts under all load conditions will therefore be seen by the examiner.

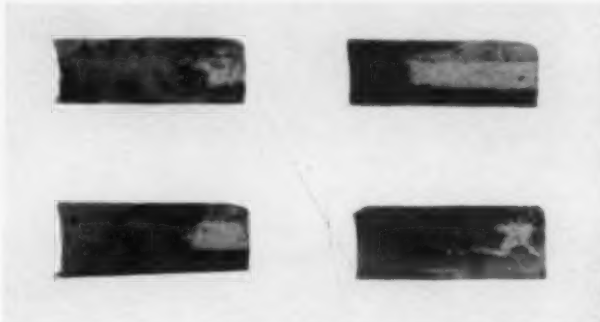


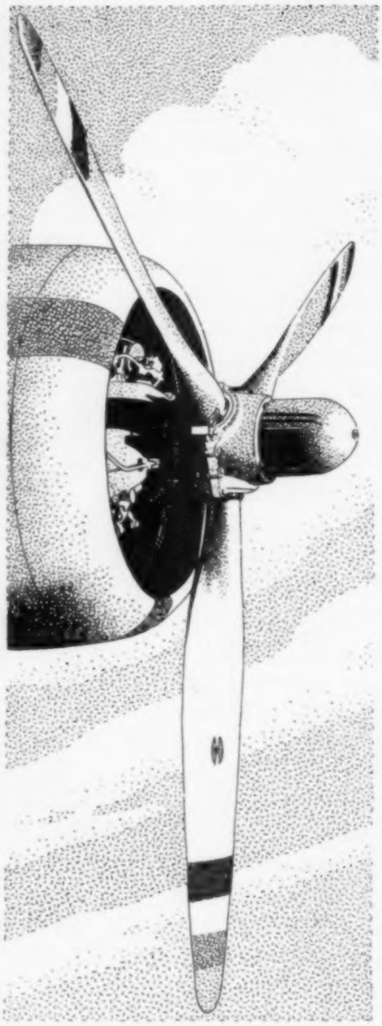
Fig. 4 — Four Teeth Taken From a Spur Gear After Operation in a Commercial Gear Box; the Polished Areas Show That Contact Was Concentrated at One End

The illustration Fig. 5, however, is from a gear that failed in service. This gear was "rescued" while on its way to the metallurgical department to find what was wrong with the *material!* Note that the failed tooth is broken at one end — which, incidentally, is typical of almost all failed gear teeth. The adjoining unbroken tooth tells us that failure occurred because only a small part of the tooth was actually supporting the load, in spite of the generous length provided by the designer. This gear would have been just as durable had it been designed with one-fifth the tooth width. Clearly this was a mechanical and not a metallurgical problem; the real trouble was inadequate support of the gears and other mechanical errors.

It may fairly be argued that this is an unusually severe case and that it is not typical of gear fatigue. But actually the most unusual thing about it was that it could be diagnosed before it was cut into sections and the evidence etched away.

In case of fatigue failure of mating helical gear teeth of equal strength, fatigue will always occur in the tooth that is loaded on its acute angled end, because the section is weaker at this end. Mating helical gears should be offset so that contact cannot occur on the acute angled end by any mode of deflection. This is possible only where the torque is constant in direction, as pointed out by the present author in a paper in *Automotive Industries*, Sept. 25 and Oct. 9, 1937, entitled "Factors Influencing the Durability of Automobile Transmission Gears".

All gear teeth should be designed to afford a degree of tolerance for deflections, machining errors, and warpage — as has long been standard practice in spiral bevel, hypoid and in some spur and helical gears. This is accomplished by curving the elements of the tooth contour in such manner as to concentrate the load near the centerline of the gear width and thus avoid load concentration at the weaker extreme ends of the teeth.



Warpage — The statement made in the first part of this paper (page 210 of *Metal Progress* for February) that there is no practical difference, from the standpoint of fatigue, between the various alloy steels must be amended when these steels are formed into gears, because warpage during heat treatment after cutting is one of the many processing errors that results in high fatigue vulnerability of gear teeth. However, the fatigue vulnerability due to non-uniform warpage can also be reduced by design, as has been described immediately above.

Pitting of Gear Teeth

Pitting of gear teeth is a form of fatigue that is induced by compression loads on the contacting tooth surfaces. The magnitude of the compression stresses varies with relative curvature of the contacting teeth in accordance with the Hertz formula; it also varies with the degree of load concentration at the ends of the teeth and with the applied load. The load that may be carried varies with the hardness and therefore with the strength of the material, with the temperature, and with the manner in which the lubricant is applied.

The design factors that are effective in reducing the load concentration at the ends of the teeth also reduce the compressive stress. The relative curvature (and therefore the compressive stress) can be varied by the choice of pressure angle. In general there is little to be gained by designing wide face gears except the doubtful satisfaction of dealing with smaller stress numbers.

In high speed gears, pitting may occur when gears are transmitting no load. This is sometimes seen in the reverse idler gear of automobile transmissions. Although this form of transmission trouble is rare and occurs only when other conditions, such as hardness, are unfavorable, it serves to emphasize the part played by the lubricant in promoting fatigue. A reverse idler running submerged in oil will trap the oil between the gear teeth and if the clearances are small will induce extremely high surface pressures. We are all familiar with the high temperatures that are generated in gear boxes when too generously supplied with oil, but we do not always interpret this as a fatigue hazard.

High speed gears should be lubricated by jets of low viscosity oil directed at the teeth as they are *coming out* of mesh, not on the incoming side. Proper lubrication will wash away the heat of friction while it is still at the surface and will prevent excess oil from reaching the contacting teeth, providing the sump is dry.

There is evidence indicating that oil further contributes to pitting fatigue by entering surface fissures where, under hydrostatic pressure, the fissures are extended until pieces are lifted out of the surfaces of the teeth. This is described by Stewart Way in an article on "Gear Tooth Pitting" in *Electric Journal*, 1936, p. 175.

Compiled by F. R. Morral

ELECTROPLATING METALS

Sheet 1

Metals	Plating Solution: Grams per Liter	Anodes	Current Density; Amp/Sq.dm.	Voltage; Volts	Temp., °C.	pH	Current Efficiency; %	Thickness Coating	Uses
Brass	$CuCN$ 26.2 $Zn(CN)_2$ 11.3 $NaCn$ 45.0	75% Cu 25% Zn	1.0		27-35	10.3 to 11.0	75	0.5-5.0 μ	Rubber bonding
	$CuCN$ 27.0 $Zn(CN)_2$ 9.0 $NaCN$ 55.25 Na_2CO_3 30.0 NH_3 1.2	80% Cu 20% Zn	0.3 to 0.5	2-3	24-38				Difficult to plate directly on malleable cast iron and stainless steel
	$CuCN$ 18.0 $Zn(CN)_2$ 10.15 $NaCN$ 12.0		0.4		26				
Cadmium	CdO (a) 23-39, (b) 20-32 $NaCN$ 86-131, 66-110 Addition Agent	Soluble-Cd Insol.-Steel	0.5 to 5.4		20-35		85-98	*N.S. 0.0125 mm. O.S. 0.0075 –"– T.S. 0.0038 –"–	Finish coating by bright dip
Chromium	Cr_2O_3 400 SO_4 4	Insol.-Pb	4-10				10-15	0.00015 to 0.00050 mm.	Decorative
	CrO_3 250 (SO_4) 2.5		5.7-15.5		40			0.025 mm./hr. at 55°C. and 31 amp/sq.dm.	Hard plate at least 25.4 μ thi
Cobalt	$Co(NH_4)_2(SO_4)_2.6H_2O$ 175	Cast & rolled Cobalt	0.4-4.2		Room	5.5+	90-98		
	$CoSO_4$ 278 $NaCl$ 17 H_3BO_3 45		3.8-17.5		Room	5	100		
	$CoSO_4$ 278 NaF 14 H_3BO_3 45		3-5		R.T. and up	5.2	83-93		
Copper	$CuSO_4.5H_2O$ 180 H_2SO_4 45 Glue 0.003	Cast or rolled Cu	3-6		21-50		100		Electrotyping
	$CuCN$ 120 $NaCN$ 135 { $NaOH$ 30 or KOH 42 } Brightener 15 Anti-pit agent 1.5	Electrolytic Cu	1.2-11	(a) 1-2 (b) 3-4	75-85		100	0.051 mm.	Bright deposits up to this thickness mostly used for plating. High speed bath
	$CuCN$ 15 $NaCN$ 23 Na_2CO_3 variable	Cast Cu or Electrolytic Cu				variable		0.0127 to 0.0254 mm.	Used for strike cleaning and some plating
	$CuCN$ 26 $NaCN$ 35 Na_2CO_3 30 Rochelle Salt 45 $(KNaC_4H_4O_6.4H_2O)$		7.5		50-80	12.2-12.8 (av. 12.6)	60-30% at 55°C. 70-40% at 70°C.		Striking, plating more easily controlled, heavy deposits. Base coating on steel to be coated with Ni or
Gold	Metallic Au 2.1 (as fulminate or cyanide) KCN 15.0 Na_2HPO_4 4.0 Na_2CO_3 variable	Insoluble; or Soluble Gold	0.11 to 0.54	2-5	40-80		100%	0.0003 mm.	Cu, Brass, Ni and Ag readily plated. Steel must be plated first with one of the above
	"Salt water process" Metallic Au 1.2 $Na_4Fe(CN)_6.10H_2O$ 15.0 $Na_2HPO_4.12H_2O$ 7.5 Na_2CO_3 4.0 Na_2SO_3 0.15	Zn	0.54	2-3					
Iron	$FeCl_2.4H_2O$ 400-500	High purity Fe	6.5		90	0.01 N HCl			
	$FeSO_4.(NH_4)_2SO_4.6H_2O$ 350	–"–	7.0		60	6.0			To built up undersized machine parts
Lead (Lead continued on sheet 2)	$2(PbCO_3).Pb(OH)_2$ 150 50% HF 240 H_3BO_3 106 Glue 0.2	Corroding or chemical Pb	0.54 to 5.4 (av. 2.2)		25-40		100%	up to 0.025 mm.	Gives satisfactory plate directly on steel. Fine grained dense deposits

Modern Electroplating: paper–(1) p. 88; (2) p. 103; (3) p. 120; (4) p. 148; (5) p. 158; (6) p. 174; (7) p. 188; (8) p. 200; (9) p. 215; (10) p. 224.

Note: (a) barrel plating
(b) still –"–

* Minimum thickness of the three types specified in A.S.T.M. specification A165-40T

A Versatile Metallographic Polishing Process

By Mildred Ferguson

Westinghouse Research Laboratories
East Pittsburgh, Pa.

THERE APPEAR to be nearly as many methods for polishing metallographic specimens as there are laboratories. Consequently a note on another method may be superfluous, but a particularly satisfactory procedure has been in use at the Westinghouse Research Laboratories for several years and has been applied to a wide variety of materials, including carbon brushes and glass-metal seals, as well as many types of metals and alloys. This uses, in one step of the procedure, ordinary paraffin disks and abrasive suspended in soap solution. It is noted in the article on Metallographic Polishing in the ⊕ Metals Handbook, and is worthy of further emphasis.

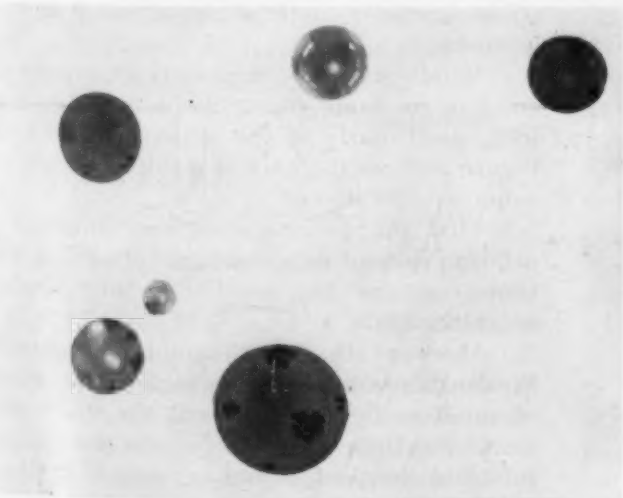
In 1925, R. G. GUTHRIE recommended the use of a paraffin-covered brass disk with soap solution as a lubricant. Turkish emery, followed by tripoli for some specimens, were the abrasives he used on paraffin for the intermediate steps between grinding on a fine-grained emery wheel and final polishing with levigated alumina on a cloth base. His purpose in substituting paraffin for cloth was to reduce the thickness of the amorphous film of metal and obtain a more nearly flat specimen.

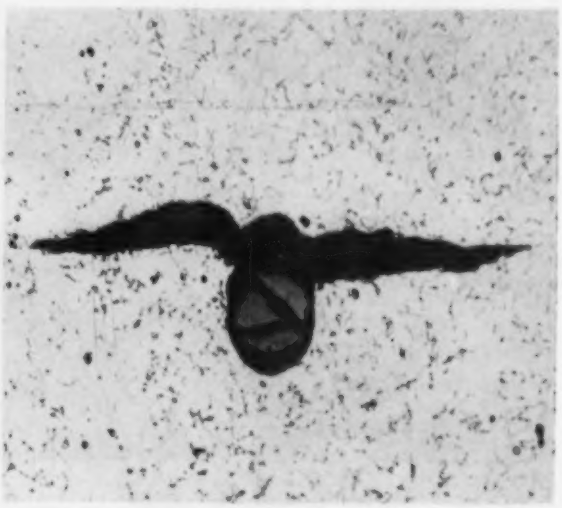
R. L. DOWDELL and M. J. WAHL, at the University of Minnesota, in 1933 included paraffin disks impregnated with No. 150 carborundum and No. 400 alundum in their procedure. However, before 1933 it was the standard practice of at least two laboratories in the Pittsburgh district to use paraffin bases with the abrasive in the disk or applied in suspended form in soap solution.

The order of procedure at Westinghouse is briefly this:

1. Rough grinding to a flat surface on the A.S.M. metallographic grinder.
2. No. 100 carborundum in 1:1 liquid soap solution on a paraffin disk.
3. No. 600 aloxite in 1:1 soap solution on paraffin.
4. No. 3 Fisher levigated alumina in distilled water on a "selvyt" cloth base.
5. Magnesium oxide, "shamva", on "selvyt" or white kitten's-ear broadcloth. (This last step is used only where fairly high magnifications are required or for soft metals.)

Ordinary paraffin of 55° C. melting point is satisfactory. A good grade of green soap solution is essential. The melted paraffin is poured into a flat shallow aluminum disk previously heated to encourage adherence. A plane surface is obtained on the paraffin disk with a simple adjustable





Retention of Inclusions

Fig. 1 — Siliceous Inclusions in Steel, × 500.

Fig. 2 — Fractured Inclusion in Crack, × 100.

leveling device. After a wheel is used a few times the tendency for a wax film to stick to the specimens disappears, due no doubt to hardening of the wax surface by charging with abrasive and by packing of the porous paraffin.

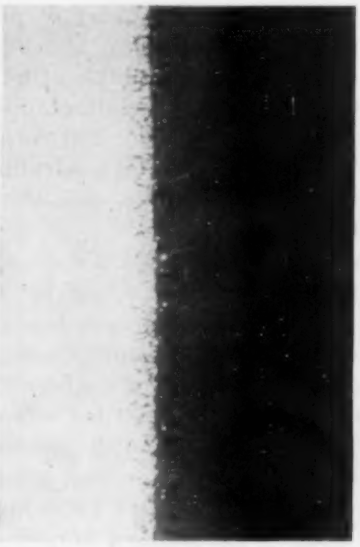
Well-known advantages of a procedure using paraffin disks instead of cloth are the minimizing of polishing pits, the ability to maintain sharper edges, the retaining of inclusions, and the economy in time required for polishing and in cost of material. However, the chief attraction is its applicability to the large variety of specimens of interest in an electrical manufacturing industry.

A few extreme cases will give an idea of its possibilities.

One of the most difficult tricks of polishing is to retain inclusions. Figure 1 shows inclusions of varying silica content in a ferritic matrix. Figure 2 shows a fractured inclusion miraculously retained in a "fish-eye" of a weld (rupture formed prior to tensile fracture in all-weld test pieces which have not been annealed).

A procedure that can be adapted to both very soft and very hard materials is unusual. Figure 3 shows electro-graphitic carbon, a very soft material which can be shaved with a finger-nail. Figure 4 shows a glass-to-metal seal in which the metal, "kovar", is relatively soft. (Gray irregular material appearing at the joint is oxide.)

Soft Material
Fig. 3 — Electro-Graphitic Carbon, × 80.



Hard and Soft Combinations
Fig. 4 — Metal to Glass Seal, × 500. Fig. 5 — Graphite in Cast Iron, × 1000.

Retention of Fine Detail
Fig. 6 — Troostite (Fine Pearlite), × 2000.

Metallographists frequently experience difficulty in retaining coarse graphite flakes in cast iron, particularly if the matrix is not ferritic. Figure 5 shows the normal results obtained when using paraffin disks.

That the process does not obliterate fine detail in spite of its speed is seen in Fig. 6, which shows nodular fine pearlite at 2000 diameters magnification.

Much of the metallographic work at the Westinghouse Laboratories requires the detection of small surface changes and the study of failures. For these cases the paraffin disks help one to obtain sharp edges and to retain in cracks any oxide or penetrated metal.

Bits and Pieces

(Metallurgicus' Own Page)

Wanted, an Inspection Method

In mass production — now as never before — it is necessary to make sure that a series of automatic operations remain in adjustment, and that any deviation that throws the product off specification limits be caught immediately, before a large quantity of rejects (scrap) is made. An instance would be the carburizing, hardening and tempering of rollers. The better and prompter the inspection method for hardness and case depth, the closer to the danger point the operations could be set. For example, valuable furnace time could be saved by avoiding the necessity of "over-casing" just to be sure you'll always have enough.

Does anyone know of a good fast check for hardness and depth of cases — one that can be put right into the production line?

METALLURGICUS

Computations of Hardenability; Effect of Undissolved Carbides

In the February 1943 issue of *Metal Progress*, METALLURGICUS questioned the accuracy of calculating hardenability from chemical composition in the presence of undissolved carbide in the austenite. Of course, Grossmann's method was never intended to be used on materials which consisted of inhomogeneous austenite, as was strongly pointed out in his original publication.

The presence of excess carbide alters the hardenability of steel (that is, the rate of decomposition of austenite) by *(a)* lowering the carbon content dissolved in the austenite and *(b)* providing sites of nucleation for the formation of pearlite.

While undissolved carbides are common in chromium and molybdenum alloy steels, they can also affect the results of heat treatment in a plain carbon steel. This will be shown for a hyper-eutectoid carbon toolsteel of the following analysis: Carbon 1.06%, manganese 0.26%, silicon 0.13%, chromium 0.02%, nickel 0.02%, sulphur 0.019% and phosphorus 0.011%.

This steel was homogenized by holding a proper time at 1700° F. Two samples then had a grain size of 5¼ and 4¾, as determined by fracture. Microscopic examination of quenched pieces revealed no excess carbide. The ideal diameter was calculated as 0.99 in., assuming grain size of 5, and using Grossmann's multiplying factors for all elements with the exception of carbon, for which Austin, Van Note and Prater's factor of 0.45 for a 1.1% carbon steel was used. (Grossmann's carbon factor extrapolated to 1.06% carbon gives a slightly lower value.) Ideal hardenability was then determined experimentally and was found to be 0.96 and 1.02 in. for the two pieces with 5¼ and 4¾ fracture grain size. These figures agree well with the calculated value of 0.99 in.

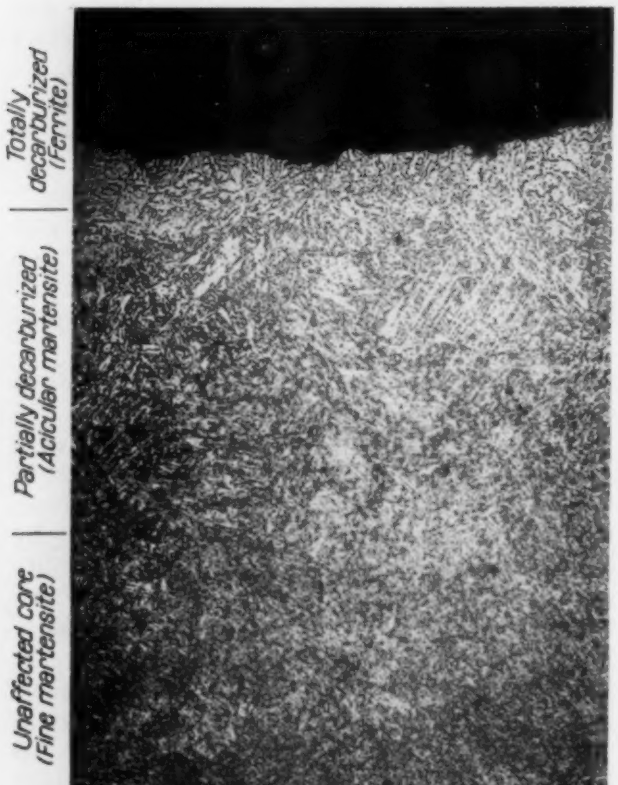
Presence of excess carbide in the steel when quenched from 1450° F. materially lowers the hardenability. The ideal critical diameter at a grain size of 8 was found experimentally to be 0.55 in. *Calculated* ideal diameter, obtained from the D_I for homogeneous austenite (0.99 in.) by using Grossmann's grain size versus hardenability chart, was figured to be 0.78 in. Actually the carbon content of the austenite is not 1.06% but is nearer to 0.85% at a temperature of 1450° F. Thus, using the Grossmann carbon factor corresponding to this carbon content at a grain size of 8 we compute a value of 0.62 in. for ideal hardenability, a closer agreement to the observed hardenability. Still neglected, however, is the nucleating effect of the undissolved carbide.

It is apparent that, to calculate hardenability from chemical composition of steels with excess carbide, a correction factor is required to account for deviations from homogeneity in addition to the multiplying factors for the different elements. Since the presence of carbide forming elements and variations in deoxidation practice, initial

structure and austenitizing time, as well as variations in austenitizing temperature, markedly affect the degree of homogeneity, the complications in devising the correct factor are many. Rough estimates can be made, however, which yield satisfactory results for plain carbon hyper-eutectoid toolsteel. (George A. Roberts, Research Metallurgist, Vanadium-Alloys Steel Co.)

Decarb in Complex Alloy Steel

We recently had some difficulty in estimating surface changes in some forgings made from heat treated nickel-chromium-molybdenum plate. Lines of demarcation between totally decarburized, partially decarburized, and unchanged zones were very poorly developed when the samples were annealed at 1300° F. In further experiments specimens were submitted to a forging heat, air cooled and reheated to 1320°,



Micro at 100 Diameters of 4340 Steel, Heat Treated To Bring Out Surface Zones. Etched in 4% Nital

1340°, 1360° and 1380° F. respectively and air cooled. This series was examined after polishing and etching but showed little improvement in demarcation over the annealed specimens.

Another series was heated as above but water quenched. The metallurgical microscope showed no improvement in zonal demarcation in the specimens quenched from 1320° and 1340° F., a fair improvement in the 1360° F. and a substantial improvement in the 1380° F. specimen.

The last mentioned heat treatment, just above Ac_1 or 1330° F., produces a martensitic structure in the unaffected metal; the almost totally decarburized skin shows up as a ferritic structure; the area partially decarburized is shown as a coarse acicular martensite which gradually becomes finer as the carbon content reaches that of the unaffected metal. The latter is not marked by a sharp line of demarcation but can usually be determined fairly accurately.

The adjoining photomicrograph shows the structure described on a plate of 4340 steel after subjecting to heating for forming, reheating for normalizing, reheating for oil quenching and tempering, and then subjecting the sample to 1380° F. followed by water quenching for determination of decarburization. Our interpretation of the various zones is shown. It is much easier to distinguish them by visual examination than by photography. (Merrill A. Scheil, Director of Metallurgical Research, A. O. Smith Corp.)

Spot Test for Manganese in Steel*

Allow one drop of nitric acid (1 to 1) to act on the cleaned surface of the steel until the reaction is practically completed. Dip a piece of filter paper, about $\frac{1}{32}$ to $\frac{1}{16}$ in. square, into this test drop until it is completely soaked and then deposit it in the bowl of a spot-test plate. Then add the following to the test paper: Two drops of nitric acid (1 to 1), 2 drops of 0.4% silver nitrate solution, and 1 drop of saturated ammonium persulphate solution (or some small crystals of solid ammonium persulphate). Mix well with the point of a glass rod.

In the presence of manganese, the solution assumes a reddish to a reddish-violet color in 5 to 10 min. Warming the test plate hastens the action, but is really not necessary.

The above is a qualitative test. If the amount of manganese is to be estimated, as a routine test, it is necessary to use equal amounts of the test

*This method, adapted from one originally published in *Archiv für das Eisenhüttenwesen*, September 1941, was received simultaneously from H. G. Holtz, metallurgist for Carnegie-Illinois Steel Corp., and Albert Neudoerffer, plant metallurgist for SKF Industries — both thereby warranting the receipt of an book of their choice, the reward for publishable items in "Bits and Pieces".

drop and hence the time of solution should be uniform and the pieces of filter paper should be of correct and equal size. For low manganese steels the filter paper can well be $\frac{1}{16}$ in. square. If the steels have 2% manganese and over, the $\frac{1}{32}$-in. square will be better. Size is important since larger amounts of manganese cannot be oxidized by the quantities of reagent stated, nor will the resulting colors permit comparison.

Of course the lighter the red the lower the manganese or, vice versa, the deeper the reddish purple the higher the manganese content. It is best, until experience is gained, to use a standard as comparison, and make about three tests on each steel. If one standard is a 0.35% manganese steel the test will be faint red. For a 1.5% manganese steel it will be a very deep red. A difference of 1% manganese is unmistakable. Detection of 0.5% differences is quite easy, and a skilled tester can correctly distinguish steels which vary by 0.2%.

Cobalt is about the only interference, and it is unlikely to be present in the steel.

Timer for Photomicrography

I have frequently heard metallographers wish for an exposure meter sensitive enough for microscopic work. Although never having seen a commercial light meter which would give adequate readings when used at the ground glass, the following system has been successful in securing uniform density for both medium and high power photomicrography:

With the specimen in place, and equipment focussed on the desired field, the filter and eyepiece are removed. A General Electric DW 48 light meter with cover off is then placed into the position shown in the halftone, a reading taken, and by using the adjoining chart the proper exposure can be determined in relation to the eyepiece and the bellows draw used. This method will automatically compensate for any change in objective, diaphragm openings, light intensity, or metal structure. Maximum detail will be assured, since every negative will be of optimum density. Printing times can then become standardized over a narrow range. (J. L. Waisman, Metallurgist, American Car and Foundry Co.)

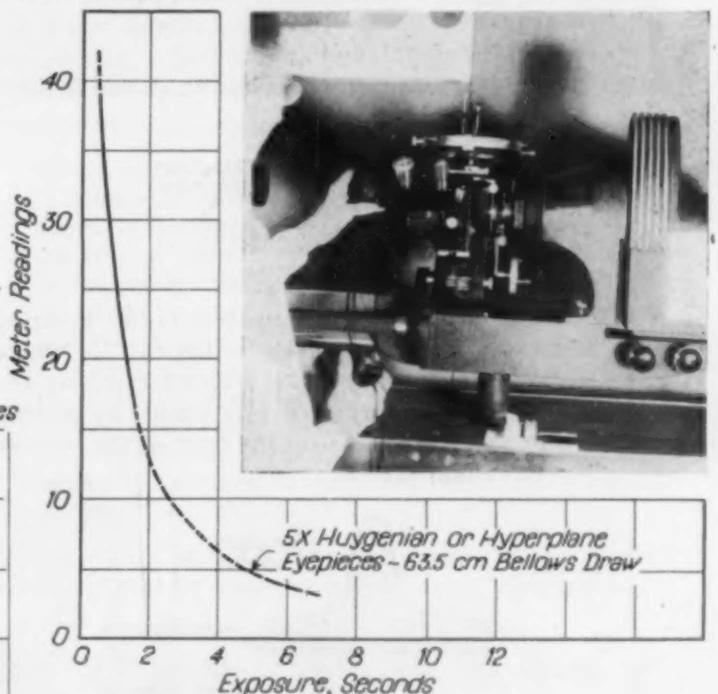
Hard Spots Formed During Inspection

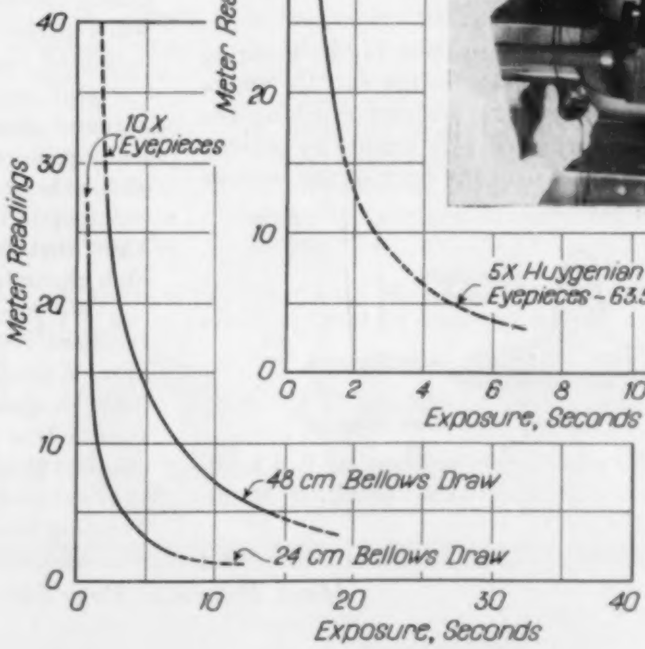
A heat treated steel forging for an aircraft shock strut had been machined for some little time in our machine shop with very little difficulty. The part was made from S.A.E. X-4130, heat treated to a tensile strength of 125,000 to 145,000 psi.

Suddenly considerable difficulty was encountered. Milling cutter teeth were chipped and broken after milling only a few parts. When the cutter failed it was noticed that the machined part showed small glazed areas, whose hardness ranged from Rockwell C-40 to 50. Such hard spots were difficult to account for, because the remainder of the part tested C-26 to 28.

When examining the heat treated sand blasted surface of the parts prior to milling it was noticed that a few showed small blue spots in the area to be milled. The hardness of these spots was checked and showed Rockwell C-40 to 50. We immediately suspected the magnetic inspection machine, in line between heat treating and milling. Examination revealed that a solid copper block was inserted in a recess of the part (the area to be milled) to enable one head of the

General Electric DW 48 Light Meter Reading Vs. Exposure for Bausch & Lomb Metallographic Outfit Using Yellow Green Filter and Various Eyepieces





magnetic inspection machine to maintain good electrical contact. This copper block had become considerably roughened with use; electrical contact was poor and arcing sometimes took place.

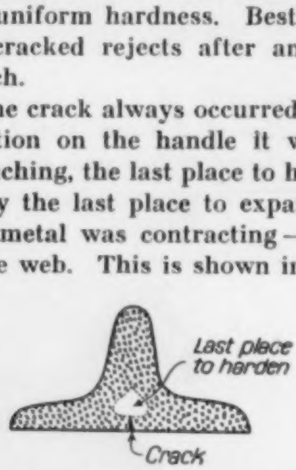
We concluded that arcing caused localized heating to a point above the critical temperature and the surrounding cold metal did an excellent job of quenching. A change in the copper block to insure good electrical contact eliminated our difficulties. (E. F. GREEN, Metallurgist, Axelson Mfg. Co.)

Hardening Cracks Avoided

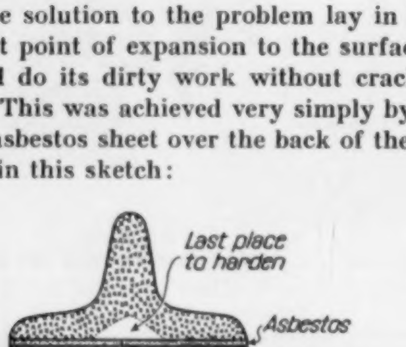
THE PROBLEM was that of hardening a trigger handle for a small anti-aircraft cannon. The Rockwell specification was C-47 to 53 on thin and thick sections. The part was made of a plain carbon steel forging with 0.48% carbon. An appalling loss due to quench cracking was being experienced.

Almost every known quenching medium was tried, but the result was always the same — either uniform Rockwells were obtained along with some cracks, or the cracks were eliminated at the expense of uniform hardness. Best results gave about 6% cracked rejects after an interrupted water quench.

Since the crack always occurred in back of a webbed section on the handle it was reasoned that in quenching, the last place to harden — and consequently the last place to expand when the rest of the metal was contracting — was in the center of the web. This is shown in the sketch:



The solution to the problem lay in bringing this last point of expansion to the surface where it could do its dirty work without cracking the piece. This was achieved very simply by placing a thin asbestos sheet over the back of the web, as shown in this sketch:



The result: No cracks, while obtaining full hardness. (WILLIAM P. MATTHEW, Assistant Metallurgist, A.O.G. Corp.)

Solder, a Good Carburization Stop-Off

WHILE copper plating is the accepted stop-off to prevent carburization on spots to be left soft, some individual without copper plating equipment or the time to send a few parts out to be plated can avoid a delay on some war production by using solder. Even though the solder is liquid at carburizing temperature, 1700° F., the film is maintained in sufficient density to prevent carbon from entering the steel.

Solder with tin content as low as 20%, balance lead, will work. It can be applied by dipping, with an iron, or with a torch. The surface must be clean and free of scale, well fluxed to insure a good adherent coating. A very suitable and effective flux is the eutectic mixture of 72% zinc chloride, and 28% ammonium chloride, by weight.

Operations on a production basis were:

1. Clean parts are immersed into molten flux to depth it is desired to protect.

2. Fluxed parts are then immersed in molten solder (750 to 850° F.) to desired depth. Solder is protected from the atmosphere by layer of flux.

3. Parts are shaken to remove excess solder, then immersed in cold water. This removes the flux, cools the part for further handling and institutes a slight rusting action which prevents the solder from flowing when parts are heated. (GLENN THIERSCH, Service Engineer, E. F. Houghton & Co.)

Contaminated Thermocouples

USERS of modern controlled atmosphere furnaces, especially those containing ammonia gas additions, should be on guard against erratic temperature control due to thermocouple failure. Leaky protection tubes are usually indicated when furnace temperatures creep up above the indicated control temperature.

Our experience has shown that a new chromel-alumel couple, No. 8 gage wire, in a leaky protection tube will go bad in a short space of four hours. On examination the chromel wire is found to be both brittle and slightly magnetic. The tubes that go bad are of the 18-8 or other high chromium-nickel steels.

We have found that pure nickel will give excellent results in such an atmosphere. However, if there has been any welding done on the tube, be sure to double check for leakage. Don't assume that the tubes are gas tight until you have checked them under air pressure. You may save yourself plenty of future trouble. (F. KUNK, Heat Treating Dept., Wm. Powell Co.)

Information supplied by an Industrial Publication

Efficient utilization of recoverable alloys in foundry scrap, which is of vital importance today in foundries making alloy castings, depends primarily on thorough scrap segregation.

The principal factors to be considered in segregation are: positive identification of scrap, adequate storage facilities and constant supervision.

Several methods of sure identification are available. For example, riser shapes can be varied according to composition. Core wires can be inserted in sprues. Molds can be marked to indicate special handling of sprues, gates and risers. Paint of different colors applied after shaking out is a simple, effective method.

Adequate storage space implies first, sufficient room to keep scrap segregated in storage. The amount of space provided should also take into account the ultimate disposition of the scrap. That is, will it be used by the foundry storing it, or be allowed to accumulate before shipment elsewhere?

Proper and continuous supervision is essential to thorough segregation. In fact, it is doubtful if any segregation program will be completely effective unless someone equipped with adequate authority is made directly responsible for maintaining it.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

MOLYBDIC OXIDE—BRIQUETTES FOR THE CUPOLA • FERROMOLYBDENUM FOR THE LADLE

MOLY

Climax Mo-lyb-den-um Company

500 Fifth Avenue • New York City

Pathways

(Continued from page 723)

is a source of many and expensive rejects.

The fluorescent oil method has already been described at the annual meeting of the American Society for Metals in October, 1942[7] and needs no further description here.

To sum up, we may say that in as far as strength of a structure or machine is concerned, the engineer must solve four problems:

1. What are the applied working loads, static and dynamic, including those due to vibration?

2. What is the working strength and the permanency of the available materials?

3. How is the load locally distributed at changes in section among the component parts, and in their fittings and attachments?

4. What local sources of weakness and occasional defects will be encountered and with what degree of certainty may they be eliminated?

Enough has probably been said to indicate that modern progress in engineering practice, in metallurgical knowledge, in strain instrumentation, and in non-destructive inspection are all taking their appropriate places in reducing the factor of ignorance which has placed an undue burden of weight and expense on many structures and machines. Many of the new tools are of direct use in metallurgical research. Even the practicing metallurgist concerned with plant problems should know about these things, at least in a general way, for they will frequently lead to a correct rather than an assumed solution of failures in production, inspection, or service.

References

1. A. V. de Forest, "Measurement of Propeller Stresses in Flight", J. Aeronaut. Sci., Vol. 4, No. 6, April 1937, p. 227.

2. A. V. de Forest, "Some Complexities of Impact Strength", Am. Inst. Mining Met. Engrs. Tech. Pub. No. 1341, Howe Memorial Lecture, 1941; Trans. Am. Inst. Mining Met. Engrs., Vol. 145, Feb. 1941; Metals Tech., Vol. 8, No. 5, August 1941.

3. K. J. DeJuhasz, "Graphical Analysis of Impact of Elastic Bars", J. Applied Mechanics, Vol. 9, No. 3, Sept. 1942, p. A-122.

4. A. V. de Forest, Greer Ellis and F. B. Stern, Jr., "Brittle Coatings for Quantitative Strain Measurements", J. Applied Mechanics, Vol. 9, No. 4, Dec. 1942, p. A-184.

5. Charles Lipson, "Methods of Stress Determination in Engine Parts", paper for Soc. Automotive Engrs., Detroit, Jan. 11-15, 1943.

6. F. B. Doane, "Principles of Magnaflux Inspection", 2nd Ed., Photopress, Inc., Chicago, 1942.

7. Taber de Forest, "The Fluorescent Penetrant Method of Detecting Discontinuities", Preprint No. 19, 1942.

Quench

(Continued from page 715)

are referred to — and they have the least permissible temperature drop before Ar_3 is reached, and the hazards Sherry mentions are encountered.

3. Modern steels are "grain size controlled", so grain growth does not seriously result from moderate heating past Ac_3 or from holding at heat. But in the good old days, to attain the desirable fine-grained structure, the temperature of quenching had to be as little beyond Ac_3 as possible, and the time as short. So the blacksmith watched for the indications that the critical had been passed, and then quenched.

Anyhow, the "rule" does not apply today, and that is the significant thing.

Bill Woodside, d'Arcambal, Stagg, and others of similar lifetime experience, should be able to confirm or deny *(a)* whether the "rule" ever existed, and *(b)* if so, whether my guesses account for its origin.

Perhaps I should add, in order to complete the story, some words about when and why it may be very advantageous to quench from a *falling* heat.

With carbon steels, there is not much to gain, and as pointed out before, Ar_3 is not far depressed below Ac_3, so the hazard is present of quenching from within the transformation range.

With alloy steels, Ar_3 to Ar_1 is depressed considerably, and advantage may be and frequently is taken of this fact by letting the work temperature drop before quenching, with a consequent reduction in cooling velocity in the quench, thus reducing distortion and austenite retention. On some alloy carburized steels such as 4820, it is impossible to get C-60 or harder by direct quenching from the carburizing heat — but if the carburized work is air cooled (or better, cooled by transfer to a furnace at a lower temperature, say 200°), C-60 *may* be attained. And distortion will be less. The rate of cooling *before* quenching must be fairly high to get maximum depression of Ar and avoid separation of proeutectoid constituents; two salt baths are often used to produce the desired result. For example, heat to 1700, transfer to salt bath at 1500, then quench. This procedure is not new — Knowlton mentions it in his book.

The Lindberg movie "Heat Treating Hints" points out the utility of such procedure for tool steels, suggesting "quenching" in hot salt baths, then oil quenching from the salt bath. Much reduced distortion and tendency to crack is promised.

DURALOY

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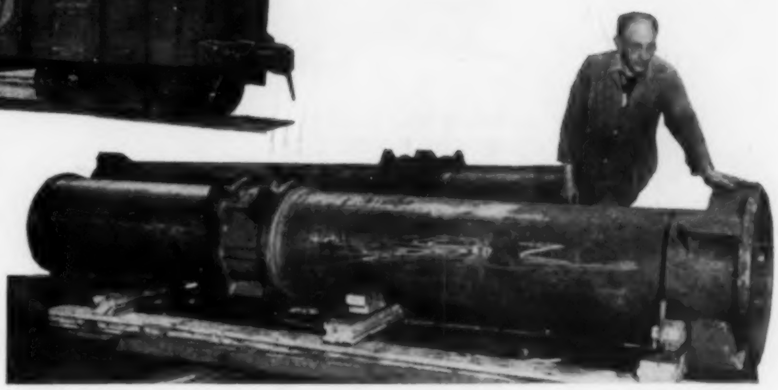
20 Years Service TO INDUSTRY



TWENTY years in the history of this country is not long. But in the history of chrome-iron and chrome-nickel castings it covers just about all of it. For we were among those who did the pioneering work in high alloy castings back in the early twenties.

All of this points to the most important requisite if a foundry is to serve industry along these lines. That requisite is *experience*.

That our metallurgists and foundrymen can look back upon so many years of service is indicative of the service they can give you today.

THE DURALOY COMPANY

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5-DU-2

Atomic Structure of Martensite

A PAPER by N. J. Petch of Cavendish Laboratory, Cambridge University, presented to the February 1942 meeting of the British Iron & Steel Institute and abstracted in *Metal Progress* for July, discussed "The Position of the Carbon Atoms in Austenite", and concluded that the carbon atoms lie at the centers of the unit face-centered cells of iron, and at the mid-points of the edges. In a second paper to the February 1943 meeting the same author considers "The Positions of the Carbon Atoms in Martensite".

Fink and Campbell first showed (in the 1926 *Transactions* of the American Society for Steel Treating) that the iron atoms in martensite assume a body-centered tetragonal lattice. Up to now, however, X-ray diffraction patterns have been unable to determine where the carbon atoms stow themselves away. Petch's brief article is therefore an appraisal of indirect evidence.

Density measurements have eliminated the possibility that carbon replaces iron atoms on the tetragonal lattice; the most likely alternative is that they are in the interstices of the iron lattice, of which there are three possible types — the centers of unit triangles, tetrahedra or octahedra made up with iron atoms at the apexes. None of these is large enough to accommodate a carbon atom (on the assumption that iron and carbon atoms act as hard spheres of [illegible] and 0.77 A radius respectively) so that as the amount of carbon in the steel increases the dimensions of the martensitic cell must also increase — which is in accord with experiment.

From a consideration of what *should* happen to the dimensions of the lattice if the carbon atom takes any of the three possible positions, and a comparison of these theoretical changes with the changes observed in the X-ray diffraction patterns and in the density as the carbon content increases in the experimental steels, Dr. Petch concludes that the carbon atoms are at the mid-points of the long edges of the martensite tetragonal cells and at the centers of the faces perpendicular to them. These positions are crystallographically equivalent. In them the carbon atoms are surrounded by octahedra of iron atoms. There is never enough carbon in solution for all these positions to be filled. This would require 2 carbon atoms per unit cell, whereas with the maximum content for high-carbon steels, there will be an average of only 0.16 per unit cell. The behavior is as if, at the most, only one in 12 of the available positions were filled.

The martensite structure is interesting because of its being tetragonal at all, and because the interstices utilized by the carbon atoms are not those which would normally be considered the largest. Perhaps the assumption that atoms behave as hard spheres is not always the correct picture. The octahedral interstice occupied, with two short and four long center-to-iron distances, may effectively accommodate a carbon atom better than the tetrahedral interstices with four medium center-to-iron distances. ●

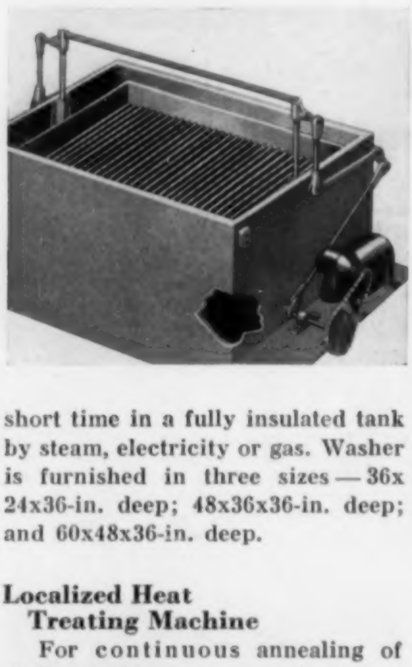
New Products

and Machinery

Metal Parts Cleaning

"Simplex", a new metal parts washer, is announced by the Sturdy-Bilt Equipment Corp., West Allis (Milwaukee) Wis. Automatic, inexpensive and compact, the new washer is said to have an action for soaking and washing that removes all foreign material. Hot or cold solutions — as determined by the particular application — may be used.

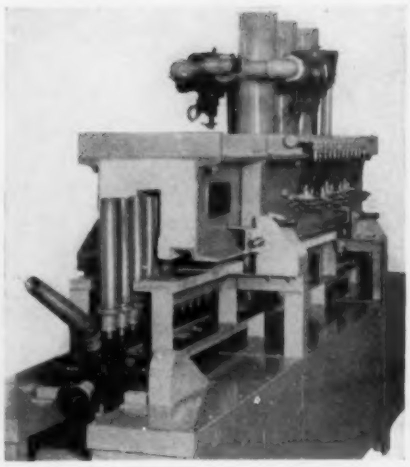
Cleaning solution is heated to a temperature of 120 to 130° F. in a



short time in a fully insulated tank by steam, electricity or gas. Washer is furnished in three sizes — 36x24x36-in. deep; 48x36x36-in. deep; and 60x48x36-in. deep.

Localized Heat Treating Machine

For continuous annealing of steel cartridge case mouths (sizes from 37 to 105 mm.) the Selas Co., Philadelphia, has built a series of



automatic machines utilizing ceramic-cup radiant gas burners in refractory-lined tunnels which let down over moving lines of cartridge cases, all as shown in the engraving above.

Each cartridge case rotates on an individual spindle during its transit through the annealing tunnel, so that preheating, heating and cooling is uniform over the desired area. In this unit for 37 and 40-mm. sizes, the tunnel is lowered sufficiently to anneal the metal down to a point several inches below the open end.

New Grinding Wheel

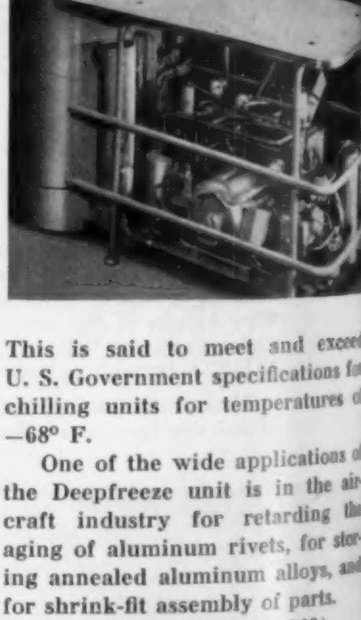
Precision grinding wheel of open, cellular construction (No. 15 abrasive content) is announced by American Emery Wheel Works, Providence, R.I. Designed for toolrooms, the open, porous construction gives plenty of chip-clearance and space for air cooling, so the hardest alloyed steels may be cut without loading or burning.

Temperature Control for Heat Exchanger

A new method for controlling the temperature in a Niagara Aero Heat Exchanger, as used for cooling industrial liquids, is announced by the Niagara Blower Co., 6 East 45th St., New York City. It is based on controlling the amount of outside air passed through the evaporative cooling chamber rather than altering the flow of liquid being cooled. Accuracy is said to be improved, with the cooling effect directly proportioned to load changes, giving a modulated, nearly straight-line temperature control, without hunting action. Less water is consumed, and when the heat exchanger is used to cool oils or compounds, there is no settling of solids, restricted flow or clogging of tubes to interrupt operations.

New Industrial Chilling Unit

New Deepfreeze industrial chilling unit is announced by Motor Products Corp. of North Chicago, Ill. Known as Model D-70, this two-stage unit provides a wide range of sub-zero temperatures down to −70° F., and removes 800 Btu. per hr. at that temperature.



This is said to meet and exceed U. S. Government specifications for chilling units for temperatures of −68° F.

One of the wide applications of the Deepfreeze unit is in the aircraft industry for retarding the aging of aluminum rivets, for storing annealed aluminum alloys, and for shrink-fit assembly of parts.

(Continued on page 792)


AXIS
Situation WELL IN HAND
Our quality sand and permanent mold aluminum castings are helping many producers of finished and semi-finished war materials to keep the "Situation Well In Hand" on the production front. Over thirty years of experience, thorough research, careful supervision and unmatched craftsmanship have made us one of the largest producers of sand and permanent mold aluminum castings. TENUAL Aluminum Castings are meeting today's demands—assuring tomorrow's needs.
TENUAL
ALUMINUM CASTINGS
Photograph shows one of our battery of squeezer machines. Man is using hand tampers. With speed all important these days, squeezer machines are playing a vital part in the mass production of castings.
U. S. WAR BONDS & STAMPS
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QUALITY SAND AND PERMANENT MOLD ALUMINUM CASTINGS

New Products

Straightening Press

A new high speed straightening press is said to eliminate the necessity for moving rounds from the press anvils to centers for checking. According to Anderson Bros. Mfg. Co., Rockford, Ill., both operations may be done in the same position. In this device when pressure is released, the spring tension on rolls lifts the shaft from the anvils, free to rotate for checking. Rolls are easily adjusted for different lengths of shafts and can be removed altogether if necessary. The press comes equipped with a calibrated indicator gage. The press is also equipped with a pressure gage so the exact force required to straighten any shaft can be determined by the operator in a short time. This is a high production machine, built to handle work up to 1½ in. d eter; larger sizes will be buil suit requirements. For occasi work a unit is built for opera by a hand hydraulic pump, w capacity up to 20,000 lb.

Largest Furnace

Representing what is believ be the largest chemically ne atmosphere furnace yet built Lithco unit is now operating 24 a day in an eastern plant mak air engine propellers. Accordin the Lithium Corp., Newark, N many problems were overcome designing this equipment. T muffle, measuring 3 ft. wide, 1 high and 25 ft. long, had to w stand working temperatures ra ing from 900 to 2100° F., depend upon the requirements. A r roller support was evolved to c pensate for expansion and cont tion. Insulation 16 in. thick a 66 specially designed burners sure even heat distribution. Cap ity approximates 3000 lb. per

This equipment has no atm phere adjustments, yet is said obtain consistently uniform dec free hardening, regardless of t steel being heated. Clean, bri work is said to be obtained at times, without cleaning, polish or descaling operations.

Induction Heating

Van Norman Machine Tool C Springfield, Mass., announces new induction heating units for face hardening, brazing, solder and other localized heating appli tions. These units of 16 and kilowatts are said to meet the av age requirements of nearly ev plant. Each machine is a co pletely enclosed unit readily ad able for parts manufactured small lots, or it can be incorpora into any production line. Units simple and easy to operate. Ope tor merely connects the pro heating coil for a particular sets the heat and quench cycle quired, and piece after piece be treated with identical resu To change from one job to anoth the operator simply changes work holding fixture and heat coil and resets the heating cycle meet the new requirements. vantages offered by induction he

(Continued on page 794)

New Products

(Continued from page 792)
ing include uniform hardening, accurate results, increased output, conservation of alloy steels, reduced spoilage, reduction in costs, and important savings in time.

Marking Ink

A marking ink which has been produced for several years exclusively for a large electrical concern is now available to the general public from Robert T. Spence, Lynn, Mass. Requirements successfully met are as follows:

An ink with which any employee can write clear and distinct small numbers or letters on any metal, glass or ceramic surface, using an ordinary steel pen. It must write and dry absolutely black. It must dry quickly and stay on, withstanding considerable abuse. It must not be affected by moisture, oils, heat or cold or any wiping which may be necessary in the process of manufacturing. It must not be messy or have any undesirable features for the operators. It must be easily removed by a simple eradicator, so that in case of some error or change, the workmen can easily and quickly remove what has been written without doing any damage whatsoever to the surface.

Large Welding Elbow

Now in production at Tube Turns, Louisville, Ky., is this 30-in. seamless welding elbow to be used in sea-going drydocks for the U.S. Navy. These are said to be the largest seamless elbows ever made.

This piping has exactly the same aperture all around the curve that it has on the straight-away and therefore presents minimum obstruction to the flow of water.

Portable Dust Collector

A new portable dust collector known as the "Safe-Aire" has just been developed by the Bargar Sheet Metal Co. of Cleveland. Its basic use is to collect dust from a single grinder or other dust-making machine, separate the dust from the air, and blow the clean air directly back into the shop. It will normally handle the dust from two 9-in. grinding wheels, is powered with a ¼-h.p. motor running an 11-in. blower at 3400 r.p.m. The machine is 37 in. high, 27 in. wide by 13 in. deep and weighs 120 lb.

Columbia TOOL STEEL

CONTROLLED MATERIAL—

A perfect name of Columbia Tool Steel. Its manufacture always has been controlled in every detail.

And now the control of distribution promises to make it more generally available.

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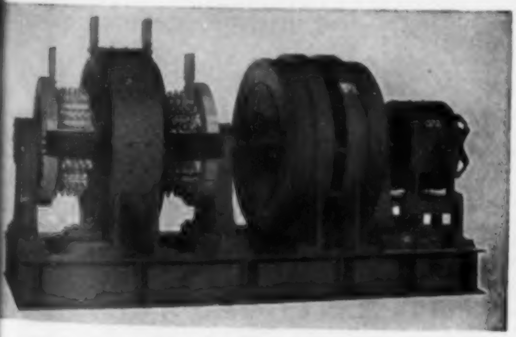
COLUMBIA MOTOR-GENERATORS

for Electro-Plating and other Electrolytic Processes



Columbia generators embody every feature essential to dependable, 24-hour operation. They are built for electroplating service in sizes of 6 to 20 volts, 500 to 20,000 amperes; for anodic treatment of aluminum in sizes of 40, 50 and 60 volts, 500 to 3,000 amperes. Columbia generators for other electrolytic processes range from ½ to 250 KW, 100 to 40,000 amperes, 6 to 60 volts.

Prompt shipment can be made on any type and size. What are your requirements?

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For Electrical Applications

USE THE NEW

CHACE NO. 6850

Thermostatic BIMETAL

This recently developed bimetal possesses an exceptionally high resistivity, high deflection rate, and is therefore especially suited for such applications as:

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- MOTOR STARTERS
- HEAT ENGINES
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- SIGNAL APPARATUS
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- CURRENT DEMAND INDICATORS
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This new bimetal can be used to improve the performance of these controls by increasing the power output for a given watts loss in the thermal element. A thicker, more rigid bimetal strip can be used without sacrificing thermal deflection. Even more important is the possibility of producing controls for lower ampere rating. Frequently this will make it possible to add lower capacity ratings to an existing line—such as a five or 10 ampere circuit breaker to the usual range of domestic breakers of 15—70 amperes.

Send for Bulletin No. B-243 which gives complete details regarding Chace No. 6850 Thermostatic Bimetal.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

New precision grinding wheel of open, cellular construction is described in folder issued by American Emery Wheel Works. Bulletin Eg-501.

Two interesting booklets illustrate presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin Eg-475.

20-page illustrated catalog on E. W. Bliss Co. line of straight side single crank presses. Bulletin Eg-380.

Working leaflet on the brazing of cemented carbide tools. Carboloy Co. Bulletin Eg-278.

Cutting Fluids, an illustrated booklet. Pate Oil Co. Bulletin Eg-496.

New 12-page illustrated bulletin describes dag colloidal graphite. Acheson Colloids Corp. Bulletin Eg-465.

Chip breaker chart shows three chip breaker types and kind of chips which will result from use of each type of breaker. McKenna Metals Co. Bulletin Eg-238.

265-page textbook covers techniques used in contour machining, laboratory controls in manufacture of precision saw bands. Doall Service Co. Bulletin Eg-297.

Multi-wash dust collectors for aluminum-magnesium metal working plants are illustrated in new leaflet by Claude B. Schneible Co. Bulletin Eg-161.

Big, comprehensive data book describes specialized oils and shows uses for hydraulic oils in metal working. Warren Refining & Chemical Co. Bulletin Eg-454.

Powdered metal presses producing millions of metal parts illustrated in catalog by Kux Machine Co. Bulletin Eg-500.

Rubberized fabric industrial gloves resistant to oil, grease and petroleum solvents as well as acids are described in leaflet by Edmont Mfg. Co. Bulletin Eg-506.

Forging presses. Ajax Mfg. Co. Bulletin Ff-105.

Horizontal extrusion presses. Hydropress, Inc. Bulletin Ff-394.

36-page pictorial story of the Ceco-stamp. Chambersburg Engineering Co. Bulletin Ff-132.

Cutting Oils. Cities Service Oil Co. Bulletin Ec-113.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin Ke-118.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin Af-335.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin Ef-360.

Forty different ways to cut machining costs. Continental Machines, Inc. Bulletin Ef-170.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin Kf-230.

Illustrated data information on cutting oils and their correct use in machining operations. National Refining Co. Bulletin Cg-479.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin Kf-433.

"Hyper-milling", a radical innovation in face-milling of steel. Firth-Sterling Steel Co. Bulletin Lf-177.

Abrasive cloth gadgets. Behr-Man ning Corp. Bulletin Nf-467.

Abrasive belt polishing machine Divine Brothers Co. Bulletin Kf-43

Surface coated abrasive belts. Min nesota Mining & Mfg. Co. Bulleti Ag-470.

Grinding and polishing with abra sive belts. Hammond Machiner Builders, Inc. Bulletin Cg-363.

Handbook on aircraft riveti operations. Cherry Rivet Compan Bulletin Dg-486.

Stampings with new Hi-Spe press. Di Machine Corp. Bullet Dg-490.

52-page tool manual. McKen Metals Co. Bulletin Dg-238.

Information and data on ne straightening press is offered Anderson Bros. Mfg. Co. Bullet Dg-491.

FERROUS METALS

"Aircraft Alloy Steels" is title the combined special stock list a data book published by Joseph Ryerson & Son, Inc. Booklet is pra tical guide to aircraft steel stoc prices, sales limitations, and speci cations. Bulletin Eg-106.

New corrosion data work she acts as check list to insure conside tion and evaluation of all factors i fluencing corrosive action. Inte national Nickel Co. Bulletin Eg-4

Enduro stainless steels. Republ Steel Corp. Bulletin Hf-8a.

Hard Facing Alloys. Wall-Colmon Corp. Bulletin Kd-85.

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Ef-387	

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Free Machining Steels. Monarch Steel Co. Bulletin Cd-255.

Tool Steels. Bethlehem Steel Co. Bulletin Ce-76.

Die Steels. Latrobe Electric Steel Co. Bulletin Ld-208.

Enameling iron sheets. Inland Steel Co. Bulletin Ld-295.

NAX high tensile low alloy steels. Great Lakes Steel Corp. Bulletin Kd-229.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin Hb-4.

Four Coppco tool steels. Copperweld Steel Co. Bulletin Cf-311.

Nitralloy and the Nitriding Process. Nitralloy Corp. Bulletin Df-116.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin Kf-429.

Steels. Boker & Co. Bulletin Kf-450.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin Ox-74.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin Nf-312.

Stainless steel. Allegheny Ludlum Steel Corp. Bulletin Df-92.

New process embodying both chemical and temperature controls for production of low carbon open hearth case carburizing steel is described in bulletin by W. J. Holliday & Co. Bulletin Bg-293.

Shop notes on the machining of stainless steels. Rustless Iron & Steel Corp. Bulletin Nf-169.

NON-FERROUS METALS

Handy & Harman has just issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin Eg-126.

Bronze. Frontier Bronze Corp. Bulletin Kf-455.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin Bg-239.

Copper Alloys. American Brass Co. Bulletin Kd-89.

Aluminum alloys for aircraft. Reynolds Metals Co. Bulletin Lf-436.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin Af-337.

Die casting equipment. Lester-Phoenix, Inc. Bulletin Kf-437.

Cerrosafe, a low temperature melting metal, used to accurately proof cast cavities. Cerro de Pasco Copper Corp. Bulletin Kf-421.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin De-307.

Brass and bronze castings. Hammond Brass Works. Bulletin Df-37

Reference on properties of lead. St. Joseph Lead Co. Bulletin Il-41

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin Gf-67.

Dowmetal data book. Dow Chemical Co. Bulletin Ec-215.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronze. Bridgeport Brass Co. Bulletin N-163.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin Cg-481.

Surface protection for magnesium. American Magnesium Corp. Bulletin Cg-482.

Standard specifications for grades of aluminum alloys (casting grades only). Federated Metals Div. American Smelting and Refining Co. Bulletin Cg-478.

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Other Manufacturers' Literature Listed on Pages 798, 802, 804, 806, 808, 812, 814 and 816.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Attractive booklet on Bunting cast bronze, sleeve type standardized bearings. Bunting Brass & Bronze Co. Bulletin Cg-473.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin Cg-483.

New engineering data sheet No. 109 announces extruded Ampco Metal produced in new extrusion mill. Ampco Metal, Inc. Bulletin Dg-175.

Everyone joining nonferrous metals needs the new 12-page Westinghouse Brazing Booklet, crammed with timely ideas for saving man-hours and critical materials. Westinghouse Elec. & Mfg. Co. Bulletin Dg-134.

WELDING

New color chart shows correct oxyacetylene flame adjustment. Air Reduction Co. Bulletin Eg-69.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin Ne-86.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin Ff-393.

Electrode quantity and welding time graph. Arcos Corp. Bulletin Ld-191.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin Ge-63.

Arc welding accessories available through General Electric Co. are illustrated in new Bulletin Lf-60.

Sciaky radial portable welder. Sciaky Brothers. Bulletin Kf-425.

Castolin Eutectic Alloys as a substitute for scarce bronze or brass welding rods. Eutectic Welding Alloys Co. Bulletin Lf-301.

Two-stage "Regolator" for producing a non-fluctuating welding flame. National Cylinder Gas Co. Bulletin Af-331.

Speed is increased 20 to 30% and power costs cut one-third with the Flexarc A-C welders described in new booklet by Westinghouse Electric & Mfg. Co. Bulletin Ag-134.

Shield Arc electrodes. McKay Co. Bulletin Gf-248.

Preheating, welding and normalizing by electrical reaction and induction is described in leaflet by Electric Arc, Inc. Bulletin Ag-468.

New precision welder with the streamlined arc is described in leaflet issued by Hercules Electric & Mfg. Co., Inc. Bulletin Nf-470.

"Sureweld" protected arc electrodes, in many types and sizes, described in illustrated literature. Hollup Corp., division of National Cylinder Gas Co. Bulletin Ag-331.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin Cg-220.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin Cg-54.

Silver Red electrodes for cutting tools and Silver Green electrodes for chisel steels are described in data sheets just added to the catalog of arc welding equipment issued by American Agile Corp. Bulletin Dg-485.

Savings in solder and other advantages of the new fusion process developed by Fusion Engineering, described in new leaflet. Bulletin Dg-488.

Modern goal in equipment design and welding technique is outlined in bulletin "New Advances in Arc Welding Equipment Design" by Harnischfeger Corp. Bulletin Dg-171.

TESTING & CONTROL

Electric heaters and controls for industrial and laboratory requirements are described by American Instrument Co. in Bulletin Eg-259.

Just out is Westinghouse's new book containing a wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin Eg-134.

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin Eg-67.

New Picker X-Ray accessory and supply catalog illustrates many accessories employed in industrial radiography. Bulletin Eg-348.

Radiographic identification of negatives with lead markers is described in leaflet by H. W. Knight & Son, Inc. Bulletin Eg-503.

X-ray crystal analysis apparatus is described and illustrated in new folder by Philips Metalix Corp. Bulletin Bg-471.

New 29-page catalog — Micromax Electric Control — has [illegible] sued by Leeds & Northru[illegible] Bulletin Bg-46.

Wheelco Instruments Co. [illegible] issued five new bulletins describing its complete line of industrial indicating, recording and control thermometers. Bulletin Bg-110.

"Kodak Products for Industrial Radiography". Eastman Kodak Co. Bulletin Ff-395.

Bristol Co. has issued series of bulletins covering automatic control and recording instruments for industrial furnaces, dryers, kilns and ovens. Bulletin Bg-87.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin If-401.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin Ff-320.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin He-4.

Radium for industrial radiography. Radium Chemical Co., Inc. Bulletin Bf-345.

Film and plate processing equipment for spectro analysis. Harry W. Dietert Co. Bulletin Af-198.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin Hb-180.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin Df-377.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin Cf-157.

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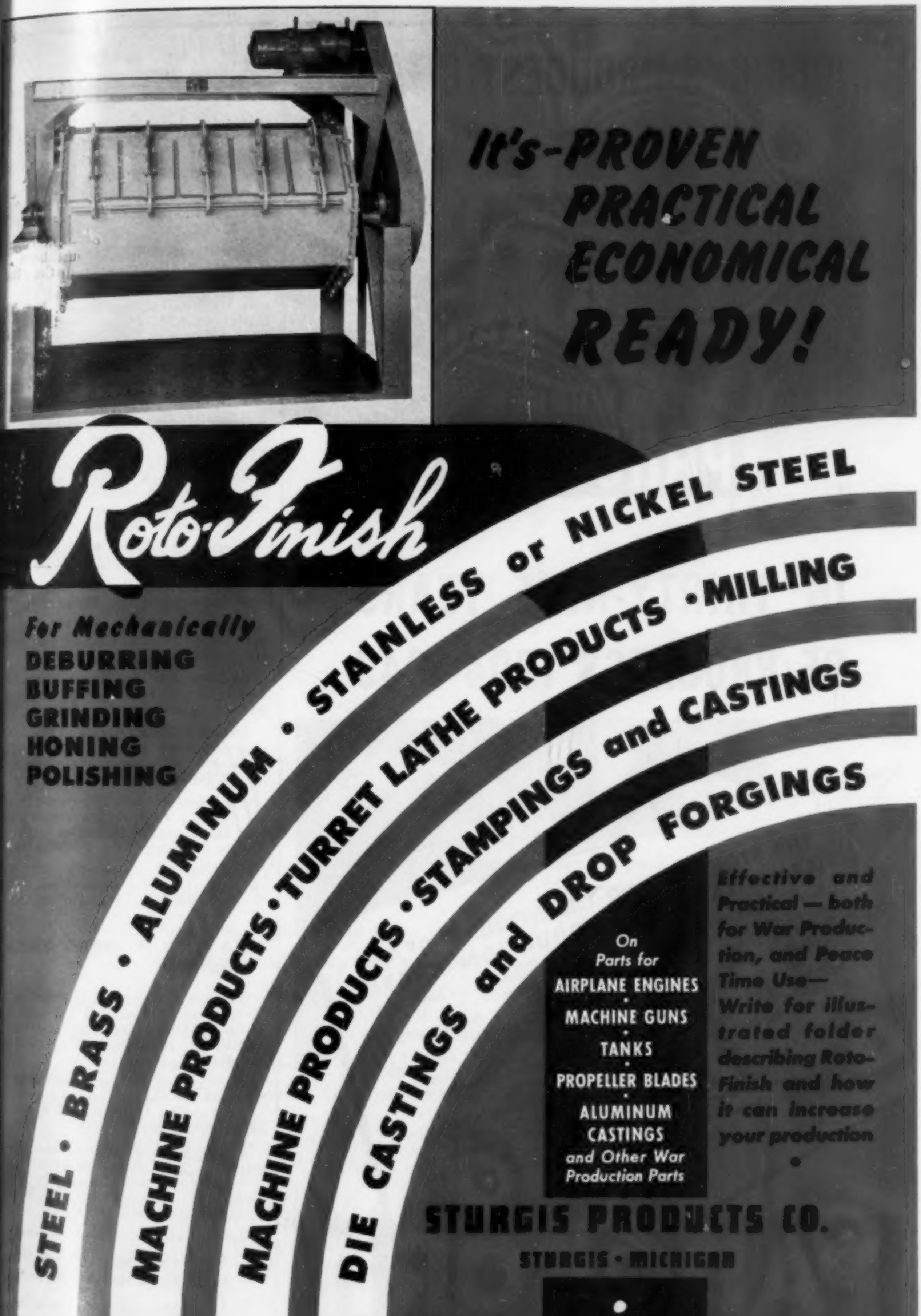
Other Manufacturers' Literature
Listed on Pages 798, 800, 804, 806, 808, 810, 812, 814 and 816.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WHAT'S NEW IN MANUFACTURERS' LITERATURE

Optical Aids. Bausch & Lomb Opti-cal Co. Bulletin Ce-35.

Metallographic polishing powder. Conrad Wolff. Bulletin Cf-368.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin Lf-7.

Metallurgical Equipment. Adolph I. Buehler. Bulletin Ke-135.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin Cf-22.

Modern Polishing. Tracy C. Jarrett. Bulletin De-303.

Potentiometer temperature indicators. Foxboro Co. Bulletin Ef-21.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin Kf-206.

Slomin high speed electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin Kf-458.

Surface Analyzer. Brush Development Company. Bulletin Kd-288.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin Kc-37.

X-Ray metallurgical laboratory service. Claud S. Gordon Co. Bulletin Nf-53.

64-page booklet on the precision control of industrial processes. Brown Instrument Co. Bulletin Nf-

Dillon tensile tester and the Dillon dynamometer are described and illustrated in new leaflet issued by W. C. Dillon & Co. Bulletin Ag-40

An innovation in the manual methods of gas analysis known as Catalysis is described in leaflet by Burrell Technical Supply Co. Bulletin Dg-21

Catalog and engineering data book on industrial thermocouples. Arklay S. Richards Co. Bulletin Dg-330.

HEATING • HEAT TREATMENT

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin Eg-399.

Homo method for nitriding is described and illustrated in new 1 page catalog by Leeds & Northrup. Bulletin Eg-46.

Furnace atmospheres, their preparation, application and relative cost are shown in new 12-page Primer on Prepared Atmospheres by Surface Combustion. Bulletin Eg-51.

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Other Manufacturers' Literature Listed on Pages 798, 800, 802, 806, 808, 81 812, 814 and 816.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin Eg-445.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin Hf-49.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin Lf-55.

Modern electric furnaces for heat treating. Harold E. Trent Co. in new Bulletin Lf-461.

8-page booklet illustrates gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin Lf-203.

Faster production with Tocco hardening, brazing, annealing and heating machines. 16-page booklet by Ohio Crankshaft Co. Bulletin Lf-145.

Kleen-well oil strainers for quench oil cooling systems. Bell & Gossett Co. Bulletin Lf-287.

Gas cracking unit for production of a protective atmosphere during heat treatment of alloy and high carbon tool steels. Hevi-Duty Electric Co. in new Bulletin Lf-44.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel. United Chromium, Inc. Bulletin Lf-463.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin Lf-443.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin Ff-286.

Heat treating furnaces. Johnston Mfg. Co. Bulletin Ff-155.

Heat treating production. Lindberg Engineering Co. Bulletin Bf-66.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin Ce-302.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin Ff-321.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin Bf-183.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin Lb-25.

Heat treatment in electric salt bath furnaces. Ajax Electric Co., Inc. Bulletin If-43.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin Cf-367.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin If-413.

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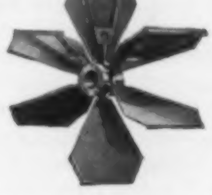

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Industrial Furnaces. W. S. Rockwell Co. Bulletin Kc-34.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin Nc-15.

Modern Shell Furnaces. Mahr Manufacturing Co. Bulletin Bf-5.

Vertical Furnace. Sentry Co. Bulletin Ne-114.

Conveyor Furnaces. Electric Furnace Co. Bulletin Be-30.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin Ce-219.

New Electric Furnace. American Electric Furnace Co. Bulletin Gd-2.

Furnace Experience. Flinn & Dreffein Co. Bulletin Bc-82.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin Bb-187.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin Ke-260.

High Temperature Fans. Michiana Products Corp. Bulletin Hb-81.

Turbo-compressors. Spencer Turbine Co. Bulletin Cf-70.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin Cf-24.

Drycolene. General Electric furnace atmosphere. Bulletin Df-60.

Dual-Action quenching oil. Gulf Oil Co. Bulletin Df-360.

Electric box type and muffle furnaces. H. O. Swoboda, Inc. Bulletin Ef-379.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin Ef-319.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin Ef-386.

Induction heating. Induction Heating Corp. Bulletin Ef-323.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin He-41.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin Ag-310.

S.F.E. Standard Industrial furnace catalog. Standard Fuel Engineering Co. Bulletin Kf-388.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin Nf-154.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequecy Laboratories, Inc. Bulletin Kc-211.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin Nf-305.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin Nf-141.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin Nf-181.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin Ag-448.

16-page catalog describes furnaces for heat treating ferrous and nonferrous metals. Despatch Oven Co. Bulletin Ag-123.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin Cg-484.

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin Cg-228.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin Cg-11.

Hagan rotary forging furnaces are described in bulletin by George J. Hagan Co. Bulletin Cg-476.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin Kf-444.

Heat treating furnaces. McCann Furnace Co. Bulletin Kf-446.

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin Kf-439.

Furnaces. Tate-Jones Co. Bulletin Kf-447.

Newly developed salt bath material for use in Martempering process. E. F. Houghton & Co. Bulletin Dg-38.

New Van Norman induction heating units are comprehensively described and typical operations pictured in attractive 8-page folder by Van Norman Machine Tool Co. Bulletin Dg-487.

New 8-page, well-illustrated catalog describes equipment for flame-hardening, flame-annealing, mechanized-brazing, preheating and other localized open heat treatments by the Selas Co. Bulletin Dg-214.

High and low temperature direct fired furnaces as well as convection types for stress relieving and drawing are described in new 8-page leaflet by R-S Products Corp. Bulletin Dg-234.

Hy-Speed Case for increasing the life of high speed tools. A. F. Holden Co. Bulletin Dg-55.

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IN MANUFACTURERS' LITERATURE

"Indium and Indium Plating". Indium Corp. of America. Bulletin Df-376.

Modern Pickling. The Enthone Co. Bulletin Ff-240.

Pickling. Wm. M. Parkin Co. Bulletin Ff-193.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin Hd-29.

Anodizing and plating equipment. Lasalco, Inc. Bulletin Kf-457.

Degreasers. Phillips Manufacturing Co. Bulletin Nc-254.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin Ge-143.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin Gf-256.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin Kf-456.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin Kf-426.

Rust Preventative. Alox Corp. Bulletin Nb-212.

Casting cleaning methods in foundries. N. Ransohoff, Inc. Bulletin Ef-381.

New industrial washing equipment is described by American Foundry Equipment Co. Bulletin Dg-112.

MELTING • CASTING • MILL OPERATIONS

Care of crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin Ff-396.

Melting, holding and alloying furnaces. Fisher Furnace Co. Bulletin Bg-195.

Ingot Production. Gathmann Engineering Co. Bulletin Ka-13.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin Bf-16.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin Db-18.

Rotary positive blower installations in several fields, including smelting, steel mill and foundry. Roots-Connersville Blower Corp. Bulletin Hf-131.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin Ga-90.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin Bf-124.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

How Research Has Produced developments that make the side-blow converter process desirable as a source of high temperature metal. Whiting Corp. Bulletin Bf-357.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin Hd-271.

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin Kf-451.

Desulphurizer for molten iron. Columbia Chemical Div., Pittsburgh Plate Glass Co. Bulletin Cg-480.

Chart for the correction of brasses for zinc loss should interest foundrymen. Foundry Services, Inc. Bulletin Dg-489.

Alloy additions to gray iron, malleable and semi-steel are discussed and newest information presented in booklet by Niagara Falls Smelting & Refining Corp. Bulletin Dg-467.

ENGINEERING • APPLICATIONS • PARTS

An engineer's handbook on electrical contacts. Fansteel Metallurgical Corp. Bulletin Eg-477.

Just released by Atlas Brass Foundry is an 84-page catalog listing sizes and prices of hundreds of finished bronze bushings and porous oil-retaining bearings. Bulletin Eg-502.

Finding list and list of sources of alloy metals. Hobart Brothers Co. Bulletin Eg-20.

200 different types of castings are described in new 32-page booklet by the Hamilton Foundry & Machine Co. Bulletin Eg-498.

Production of gray iron and semi-steel castings is described in an illustrated booklet issued by Forest City Foundries Co. Bulletin Eg-499.

Flanges and other drop forgings. Ladish Drop Forge Co. Bulletin Eg-441.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin Eg-232.

Centrifugal castings. Shenango-Penn Mold Co. Bulletin Eg-174.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin Kf-430.

Carburizing Boxes. Pressed Steel Co. Bulletin Ce-269.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin Bf-233.

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★**BUY U. S. WAR BONDS and STAMPS**

Conservation is "Personified" in Amsco Alloy *Flexboxes* . . . . .

From the time a heat treating box is first put in service, destructive forces are fighting to shorten its life: high furnace temperatures, variable temperatures during the heat treating cycle, differential heating, and corrosive vapors. All such containers are bound to burn out, crack or break, sooner or later. But the "Flexbox" design and the high heat resistance of Amsco Alloy combine to counter-attack with an effectiveness which usually makes this "later."

Patented "Flexbox" heat-treating and carburizing boxes are made of the grade of Amsco Alloy best adapted to the specific application.

The "Flexbox" body is made in three or four separate cast pieces. The sides have tongue and groove joints and are held in place by a tack weld. The sides and ends are corrugated (when practicable) to give greater strength at high temperatures, and the bottoms have legs for use in batch type furnaces, providing complete circulation around the container. The covers are light cast pieces, furnished either flat or corrugated. As in the case of all Amsco Alloy parts, X-rays of castings selected for checking minimize the possibility of placing defective parts in service.

Sufficient clearance is allowed in the joints to absorb expansion from heating of the parts, and for contraction in cooling without appreciable loss of gas. This feature is highly effective in retarding distortion or cracking of the castings. Should an occasion arise wherein it is advisable to replace a section of a "Flexbox," it can be done without difficulty.

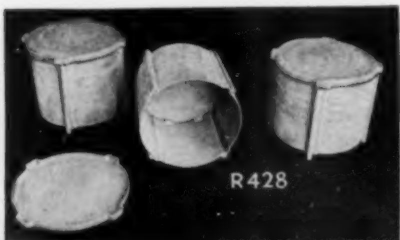
Using "Flexboxes" is one sure way to reduce heat treating box replacement costs, and to conserve metal.

Write for bulletin on Amsco Alloy "Flexboxes."

R-428 Cylindrical "Flexboxes" made in four sections.

R-666 "Flexboxes" for carburizing at 1650-1750° F. with side lugs for handling loaded boxes. Legs are welded on instead of being cast integral to avoid casting stresses.

R-610 "Flexboxes" made in three tongue and grooved sections, cover and flanged bottom which clamps to sides.



Better steel requires more scrap!

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Meehanite Castings. Meehanite Research Institute. Bulletin Bf-165.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin Ld-32.

Ledaloyl, self-lubricating bearings. Johnson Bronze Co. Bulletin Af-237.

Metal Baskets. W. S. Tyler Co. Bulletin Bf-359.

Steel Castings. Chicago Steel Foundry Co. Bulletin He-184.

Heat Resisting Alloys. General Alloys Co. Bulletin D-17.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin Bb-84.

Metal Powders. Metals Disintegrating Co. Bulletin Ec-208a.

Bimetals and Electrical Contacts. The H. A. Wilson Company. Bulletin Cf-370.

Handy wire data chart. Callite Tungsten Corp. Bulletin Ef-327.

Corrosion and heat resistant alloy. Lebanon Steel Foundry. Bulletin Ef-387.

Lead-base metals. Magnolia Metal Co. Bulletin Kf-422.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin La-23.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin Lf-299.

Standard and special shapes of seamless steel tubing are described and pictured in new leaflet by Summerill Tubing Co. Bulletin Lf-108.

Seamless pressed steel heat treating containers. Eclipse Fuel Engineering Co. Bulletin Ag-226.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin Ag-144.

48-page catalog on manganese steel. American Manganese Steel Div., American Brake Shoe & Foundry Co. Bulletin Cg-9.

Oilite precision oil cushion-bronze bearings and other powder metal bar, plate and strip stocks are comprehensively described in 140-page catalog issued by Amplex Div., Chrysler Corp. Bulletin Dg-492.

Alloy Castings. Ohio Steel Foundry Co. Bulletin Dg-40.

GENERAL

Highly interesting history of the development of piping is presented in the Spring 1943 issue of *Tube Turns Sparks.* Bulletin Eg-495.

Use Handy Coupon on Page 798 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 798, 800, 802, 804, 806, 808, 810, 812 and 814.